Field Guide

Residential New Construction

Maryland

- **Energy Efficient Construction**
- **ENERGY STAR® Homes**
- **Maryland Energy Code**

Field Guide

Residential New Construction



- Energy Efficient Construction
- ENERGY STAR® Homes
- Maryland Energy Code

©2004 Conservation Services Group, Westborough, MA.
All rights reserved. Printed on recycled paper.

Acknowledgments

Principal Author:

Bruce Harley, Conservation Services Group

40 Washington Street
Westborough, MA 01581
508-836-9500

577 Boulger Road
Stamford, VT 05352
802-694-1719
bruce.harley@csgrp.com

We welcome any editorial or technical comments regarding the material in this guide. Please contact the author at the address above.

Funding for the original field guide was provided by the Joint Management Committee (JMC), a consortium of electric and gas utilities in New England. Northeast Energy Efficiency Partnerships, Inc. (NEEP), though a grant from the U.S. Department of Energy (DOE), directed and funded development of the current edition for Maryland. The Maryland Energy Administration provided the funds to print the Maryland guide.

Current revisions and primary technical review provided by Adam Gifford, Conservation Services Group (CSG).

The following members of CSG's project team also contributed fundamentally to this project by reviewing the material and assisting with research, design and administrative support: Natalia Berg, Michael Guerard, John Livermore, Courtney Moriarta, Mary O'Malley, Barbara Smith, Carol Harley, and Henry Spindler.

Principal review by Stephen Houle, Town of Ludlow Building Department; David Weitz, BBRS staff; Susan Reilly and Wendy Hawthorne, Enermodal Engineering, Inc.; and Robert W. Harley.

CSG acknowledges with appreciation the license granted by Enermodal Engineering, Inc. of Denver, Colorado and the City of Fort Collins, Colorado under their publication *City of Fort Collins Builder's Guide to Energy Efficient Home Construction,* ©1996 City of Fort Collins and Enermodal Engineering, Inc.

Thanks also to Betsy Pettit of Building Science Corporation, Diane Gaw, Katherine Anderson, and Pam Torrisi and Doug Hindrichs of the National Fenestration Rating Council.

Most of all, thanks is due to the numerous builders and building scientists whose pioneering work in understanding the dynamics of the house system have made this book possible.

Thank you!

ENERGY STAR and the ENERGY STAR Logo are registered trademarks of the United States Environmental Protection Agency and the U.S. Department of Energy.

Contents

1 2 3 4 5 6 7 8 9 10 11 12 13 14 A B C

Maryland Contacts

For residential energy information:

Assistant Director, Residential Programs, Maryland Energy Administration, 1623 Forest Drive, Suite 300, Annapolis MD 21403, Phone 1-800-723-6374 or 410-260-7655 or www.energy.state.md.us

For Maryland energy code questions:

Code questions to: Director, Maryland Codes Administration, Maryland Department of Housing and Community Development, 100 Community Place, Crownsville, MD 21032, 410-514-7220 or www.mdcodes.org

Development partners for the Maryland guide include:

MARYLAND ENERGY ADMINISTRATION

DHCD Maryland Department of Housing and Community Development

Northeast Energy Efficiency Partnerships, Inc.

U.S. Department of Energy Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Introduction

What is “energy efficient” construction? Many people picture a space-age house, with a wall of south-facing glass. Others think about solar power or heat. Still others think of superinsulation and high-tech windows. Energy efficient construction can include these features, but it does not need to (see Appendix B).

Any home design can be energy efficient, and with careful planning additional construction costs can be minimal. Builders who use the “house as a system” concept to plan and build their homes will have happier customers, more referrals and fewer callbacks, which in the long run will more than pay for any added costs. This guide serves as a starting point to help designers and builders understand the system approach, with an emphasis on meeting the requirements of the energy code and the ENERGY STAR for New Homes Program.

About this guide

The purpose of this guide is to provide an overview of energy efficient residential new construction in the Northeast and mid-Atlantic states. The focus of the text and drawings in the guide are on three main subjects:

- **Compliance with the Maryland residential energy code—** Maryland has adopted the 2003 International Energy Conservation Code (IECC). Although there are some state-specific differences, most of the code references in the guide can be used generally for any nearby state with an IECC- or MEC-based energy code.
- **ENERGY STAR for New Homes Program—**The Environmental Protection Agency’s ENERGY STAR for New Homes Program has set a benchmark for energy efficient new construction nationwide. Through the ENERGY STAR program, any home can be recognized as having met the EPA’s guidelines for improved energy performance. This guide serves as a summary of the key components of a successful ENERGY STAR project.
- **A systems approach to building—**Understanding the way different components and materials interact in a building can reduce moisture problems, indoor air quality complaints, combustion safety problems, ice dams, and other expensive callbacks. This guide provides an overview of the key components of “house as a system” building, with a focus on energy performance.

Format

This guide is divided into sections that follow a typical construction sequence. Each section has convenient tabs marked on the edge of the page, (e.g. foundation, framing, etc.) There are also special sections on the energy code, on ENERGY STAR, and on the "house as a system" approach to building.

The purpose of this guide is to provide an overview of the important issues related to building an energy efficient new home, and also to serve as a handy field reference that designers, builders and trades people can use at every step of the construction process. Each chapter has the following features in common:

- **Energy code—**The opening section of the chapter outlines what parts of the energy code you must pay attention to during that stage in the construction process. References are made to the code document itself so you can find the actual code language that relates to your situation.

Energy code requirements are highlighted in blue

Other (non-energy) code requirements that may be related to an energy concern are outlined by a blue box. Most of these requirements are drawn from the International Residential Code (IRC) for One- and Two-Family Dwellings (see Appendix B for ordering information).

- **ENERGY STAR—**Further suggestions are made about what steps you may take to help ensure ENERGY STAR guidelines are met at every step. Included are some suggestions about how costs in one area may be traded off against reduced costs in another area.
- **Going further—**This guide is intended to be a concise reference; there are numerous situations which are beyond its scope. There are many references listed in Appendix B for further reading. One of these resources stands out as exemplary, thorough, and easy to understand—the Energy Efficient Building Association (EEBA) *Mixed-Humid Climate Builder's Guide.* The EEBA *Builder's Guide,* referenced as such throughout this book, is an ideal resource for further reading and more detail drawings. See Appendix B for ordering information.
- **Detail drawings—**Most of the drawings in this guide are found at the end of each chapter. The drawings have shaded notes that refer to code requirements. **In all drawings, the dotted line (in color) indicates the location of the primary air barrier.**

1

Maryland Energy Code

This Guide Is Not the Code

The current residential energy code for Maryland is the International Energy Conservation Code, 2003 edition (IECC 2003). This guide attempts to portray these energy code requirements as completely and accurately as possible at the date of publication. However, building codes are subject to interpretation, as well as periodic changes. If you have any questions about the details of the code language, refer to the actual language in the current version of the code (see Appendix B for ordering information). Wherever possible, references are made to the specific section number from the code so you can look it up. If questions of interpretation arise, contact the Maryland Codes Administration.

Construction Types (IECC 101.4)

IECC 2003 covers all residential new construction, three stories high or less (detached one- and two-family dwellings, Group R-2 and R-4 buildings, and townhouses), and additions to existing buildings. Although IECC 2003 covers residential and commercial buildings, the focus of this guide is on low-rise residential. Most of the chapters concentrate on one- and two-family dwellings. Commercial and high-rise buildings are governed by Chapters 7 and 8 of IECC 2003.

IECC 2003 does not apply to:

- buildings that are not heated or cooled
- additions to listed historical buildings

How the Code Works

In practice, code compliance has four major elements, which are summarized below:

- General Requirements
- Compliance Analysis
- Documentation
- Plan Review and Field Inspections

General Requirements

The following is a summary of the general requirements. You must follow all of the requirements that are applicable to your building project.

- **A vapor retarder** with a perm rating of 1.0 or less (tested in accordance with Procedure A of ASTM E 96) is required on the winter warm side of insulated walls, floors, and ceilings unless ventilation is provided to allow moisture to escape **(IECC 502.1.1).**
- **Basement walls must be insulated if the basement is conditioned space (IECC 502.2.1.6).** The insulation must extend from the top of the wall to the top of the basement floor. Chapter 6 shows examples of basement wall insulation.
- **Slab on grade floors of conditioned space need perimeter insulation,** if they are on grade, or up to 1 foot below grade **(IECC 502.2.1.4).** This includes the walkout portion of heated basements, or breezeways between a garage and house that share the garage slab. See Chapter 6 for more information on slabs.
- **Air Leakage (IECC 502.1.4)**—Leaks must be sealed between conditioned space and outdoors, and between conditioned space and unconditioned space. The code specifies locations that must be sealed, and gives examples of ways to seal them. Many examples of acceptable air sealing are found in Chapters 7 and 11, with code requirements highlighted in blue.
- **Mechanical systems (IECC Section 503)**—This section has requirements for heat loss calculations, equipment efficiency, duct and hydronic pipe insulation, and duct sealing (see Chapter 9).
- **Service Water Heating (IECC Section 504)**—This section addresses minimum standards for water heating equipment. Most residential equipment is covered by federal minimum standards (NAECA 1987), and meets code minimums. There are pipe insulation requirements for re-circulating hot water systems only. Some requirements for swimming pools—both heated and unheated—are found in this section.

Compliance Analysis

Before you start building, you need to prepare a design that ensures you will comply with the code. In fact, you must do this before you can get a building permit. This is no different from any other part of the code, such as egress requirements, structural loads, etc. There are three design tools you can use yourself: RES*check* software (formerly MEC*check)*, the prescriptive tables from IECC Chapter 5, or the simplified prescriptive tables from IECC Chapter 6. All of these tools start with some information about the dimensions of your house, and tell you what R-values of insulation, and what U-factors of windows, doors and skylights you must use to comply. As an alternative, see the section on “systems analysis” on page 6-7.

TIP: The notes in the illustrations related to code details do not mention R-values. That is because the R-values are determined by your compliance analysis. Most of the code-related notes apply to the general requirements.

Thermal Envelope

Before you do a compliance analysis, it is important to define the thermal envelope of the building. See page 21 for more about the thermal envelope.

Here is a summary of the compliance methods:

RES*check* This software program is an easy-to-use compliance tool that runs on Windows. Using RES*check*:

- **Allows significant flexibility** for determining compliance specifications for most situations.
- **Allows the designer to trade off** better performance in one area, like higher R-values of insulation, to offset poorer performance in another, like higher U-factor windows. It also allows trading off higher efficiency heating equipment to offset a less efficient building shell.
- **Requires that you calculate square foot areas** for all insulated components of the building such as walls, floors, ceilings, windows and doors.
- **Is the most forgiving** in the sense that it will be the easiest way to pass the compliance test for most houses.

The software is available for free on the internet at: www.energycodes.gov. Click on RES*check* under “Free Software Downloads”. Instructions are also available with the software, and context-sensitive help menus are built in. Some things to remember with RES*check:*

- Use *gross* wall areas, including all windows and doors. RES*check* subtracts window and door area automatically.
- Don’t forget to include band joist areas—except band joists of insulated floors—in the net wall area.
- Use window frame size or rough opening for window area, not the glass or sash size.
- Input the actual heating and cooling equipment efficiencies if you are using equipment that is rated above the code minimum.

1

Code

Prescriptive Methods **(IECC Chapters 5 and 6)—**These methods allow you to look up R-values and U-factors from a table.

- The prescriptive specifications found in section 502.2.4 **give minimum performance specifications** for building envelope components, based on the heating degree days in your location and the window area of the house. You first need to calculate the window and skylight area as a percentage of gross wall area, to determine which table to use. Tables 502.2.4(1) through 502.2.4(6) are for one- and two-family homes with glazing to wall area ratios ranging up to a maximum of 25. Table 502.2.4(7) through 502.2.4(9) are for multifamily buildings with glazing to wall area ratios up to 30 percent.
- The prescriptive specifications found in section 602.1 **can only be used for one- and two-family homes with a maximum glazing to wall area ratio** of 15 percent, and for multifamily buildings with a maximum glazing to wall area ratio of 25 percent. Note that the Chapter 11 requirements in the International Residential Code (IRC) are nearly identical to section 602.1, with the exception that they only apply to 1-2 family homes. Because they are the most simplistic compliance methods, using either of these prescriptive tables will generally result in the most conservative specifications to comply, for a given building.
- **Are the least flexible—**Each category of window area and climate has several different option packages you can choose, but once you choose a package you must meet or exceed all the listed specifications from that package.
- **Require minimal calculations—**Gross wall area, overall glazing area and the percentage of glazing to wall area are the only numbers you need to calculate.
- **Are the least forgiving—**In general, the prescriptive packages are more stringent than any of the other methods.
- **Be careful** to follow the general requirements, and to read the relevant sections for detail and exceptions. Section 502.2.4 provides detail on applications of Tables 502.2.4, including special instructions for the use of steel-frame assemblies and mass walls (such as log or masonry construction), exemptions for a specified portion of window and door area, reduced ceiling R-value requirements for ceilings with "raised truss" design (see p. 98). Section 602 provides similar detail and instructions for Table 602.1.

Systems Analysis **(IECC Chapter 4)—**If you want to, you can have an architect, engineer, certified Home Energy Rater, or other energy professional perform a detailed annual energy analysis as an alternative to these approaches. Instructions on how to do this analysis are found in IECC Chapter 4.

Documentation (IECC Section 104)

Once you have used one of the design tools to determine the specifications of R-values, U-factors and equipment efficiency for your project, you need to submit those specifications as part of the building permit application process. Normally this will consist of submitting a report that is created as part of the compliance analysis. The report will be a worksheet you filled out or a computer printout, depending on the compliance method, and will have a list of the R-values of insulation (and U-factors for windows) you plan to use in the project. It's a good idea to make a copy of the paperwork for each project you submit.

Plan Review and Field Inspections (IECC Sections 102 and 105)

Building inspectors will primarily be looking to see that the house meets the general requirements listed above, as well as the specifications that you submitted when you applied for the building permit. As long as the insulation R-values and equipment efficiencies in the house equal or exceed those you got from the compliance analysis, and you follow the general requirements, you should pass without difficulty. Window, door and skylight U-factors must be equal or less than those you got from the analysis. Don't forget about these issues:

- Insulation must be installed properly (see pages 99-100), and with R-value markings visible.
- The requirements for verifying window performance are on page 61. NFRC rating labels should remain attached to all windows until they are checked by a building code official.
- Requirements for equipment maintenance information are on page 71.

Special Note on Additions

The thermal requirements for additions can be determined using the same analysis tools listed above. The addition can be analyzed by itself, **or** the entire building including the addition can be analyzed and shown to be compliant. As an alternate, the addition may be shown to comply with IECC Table 502.2.5.

In order to use Table 502.2.5, the addition must be added to a 1- or 2-family home and have:

- A conditioned space floor area less than 500 square feet
- Total fenestration area (including skylights) must be less than or equal to 40 percent of the combined exterior wall and roof or ceiling area.

Sunrooms

An addition that is one story, less than 500 square feet in floor area, but has a fenestration area of 40% or more of the combined exterior wall and roof or ceiling area, is considered a “Sunroom Addition.” If a sunroom addition is open to the existing structure, the envelope component criteria in Table 502.2.5 may be used. If a sunroom addition is conditioned space, but is thermally isolated from the existing structure, the fenestration U-factor maximum may be increased to 0.5. There are also allowances for lower R-values in the ceilings and walls (see footnotes 2 and 6 below). To be “thermally isolated,” a conditioned sunroom must meet the following criteria:

- Exterior, insulated walls, with doors and/or windows that can be closed, between the existing structure and a sunroom addition.

Table 502.2.5.
Prescriptive Envelope Component Criteria for Additions

	Maximum	Minimum R-values					
Heating degree days	Fenestration U-factor (Windows, doors and skylights)	Ceiling	Wall	Floor	Bsmt Wall	Slab edge R-value and depth	Crawl space wall
2000-3,999	0.5	R-30	R-13	R-19	R-8	R-5, 2ft	R-10
4,000-5,999	U-0.4	R-38	R-18	R-21	R-10	R-9, 2ft	R-19
6,000-8,499	U-0.35	R-49	R-21	R-21	R-11	R-13, 4ft	R-20

1 Fenestration U-factor may be the calculated area-weighted average U-factor for all windows, doors and skylights (see Appendix A).

2 Ceiling R-value is used for flat and cathedral ceilings as well as floors over outside air. Ceiling R-value minimums may be reduced to 19 (<5,999 HDD) or 24 (>5,999 HDD) for sunrooms.

3 Basement wall and slab insulation installed according to sections 502.2.1.6 and 502.2.1.4, respectively. For radiant heat slabs, add an additional R-2 to the required slab R-value.

4 Crawl space wall R-values apply only to unvented crawl spaces, according to section 502.2.1.5.

5 Existing walls, doors, and windows between the addition and the existing structure are not counted in the wall or fenestration area of the addition.

6 Wall R-value minimum may be reduced to 13 for sunrooms.

- The sunroom must have either a separate HVAC system, or be served by an HVAC zone that is separate from the rest of the structure.
- Any new walls, doors, and/or windows separating the existing structure from the sunroom addition must meet the standards in Table 502.2.5. Existing walls, doors, and/or windows separating the existing structure from the sunroom addition may be left as is.

Replacement Windows
Replacement windows and doors in existing buildings must meet the fenestration U-factor requirements in Table 502.2.5. This applies when the entire unit, including the frame, sash, and glazing, is replaced. Replacement skylights shall have a maximum U-factor of 0.6.

The general requirements of the code, and many of the details in this guide, apply to additions as well as new homes. However, many of the issues regarding moisture, air leakage, movement, etc. require extra attention wherever additions meet the existing building.

2

ENERGY STAR Qualified New Homes

The ENERGY STAR Advantage

The ENERGY STAR advantage allows builders and developers to increase profitability and market success by building homes with high levels of comfort, indoor air quality, and energy efficiency. Based on an energy efficiency guideline set by the United States Environmental Protection Agency (EPA) and the Department of Energy (DOE), ENERGY STAR Qualified New Homes are nationally recognized for greater value, lower operating costs, increased durability, comfort, and safety.

What makes an ENERGY STAR Qualified New Home?

The guideline used to qualify an ENERGY STAR Home is an annual energy analysis similar to the "Systems Analysis" compliance path for the energy code. Based on a nationwide standard for Home Energy Ratings (HERS), a new home that receives a "5-star" rating (86 or higher on a 0- to 100-point scale) qualifies for an ENERGY STAR label.

ENERGY STAR guidelines can also be met using Builder Option Packages (BOPs). A BOP is a set of EPA-approved, climate-specific specifications that can be used as a prescription for building ENERGY STAR Qualified New Homes. A BOP consists of performance levels for the thermal envelope, insulation, windows, orientation, HVAC systems and water heating efficiency. Homes that are verified using a BOP must also have diagnostic testing performed (i.e. blower door and duct leakage tests). The same minimum level of overall energy efficiency is achieved regardless of approach used qualify an ENERGY STAR Home.

The ENERGY STAR for New Homes program recognizes builders, home buyers, architects, etc. who achieve a specified level of energy efficiency with the homes that they are building. Accordingly, strengths in one part of a home's design (e.g. high efficiency mechanical systems) may be used to offset relative weaknesses (e.g. average insulation levels) in another part of the design. While there are no prescriptive specifications associated with the national ENERGY STAR for New Homes program, many states supplement the national standard with minimum requirements for particular building components. This, however, is not the case in Maryland.

Builders who build ENERGY STAR Qualified New Homes reap the benefits of:

- Increased Profits
- Increased Customer Satisfaction
- Differentiation in the Marketplace

For most builders, the upgrade to building an ENERGY STAR Qualified New Home is relatively small, especially if they are already exceeding minimum code requirements. The difference between energy code and ENERGY STAR (usually cited as a 15 to 30% improvement) can be minimized as a result of the fact that the energy analysis used for ENERGY STAR takes efficiency measures into account that the code typically does not, such as solar gain from south facing glass, a tighter building envelope, and high efficiency water heating.

For more general information on the ENERGY STAR for New Homes Program, visit the web site at www.energystar.gov/homes

How do I qualify my new home?

Any house can be brought to ENERGY STAR levels, no matter what the style. The ENERGY STAR process is easy to incorporate into your construction timetable. Here's how it works:

- **Identify a HERS Rater** in your area, using the information provided below.
- **Submit a set of your building plans** to your rater, along with any other information that the rater requests.
- **The HERS Rater will analyze your plans** and propose upgrades to bring the home to ENERGY STAR levels. The rater will work with the designer, builder, and/or client to determine the final

specifications for each project. Once everyone has agreed on an upgrade package, the rater will issue a list of project specifications, along with any program-specific documentation or forms. An energy code compliance report may also be issued at this time.

- **Inspections—**When the house is finished, the rater will do a blower door test and (if applicable) duct leakage test, as well as verifying insulation levels, mechanical system efficiency ratings, and other features of the project. Some raters may do additional inspections prior to drywall, or do tests on mechanical systems in the home.
- **Certification—**Once the final inspection is complete, the rater will issue the final energy rating, and if your home meets current ENERGY STAR guidelines it will be labeled as an ENERGY STAR Qualified New Home!

The HERS Rater will help take you through the entire process: he or she will suggest cost-effective improvements or money-saving tradeoffs, help you with energy code documentation, and ensure that energy details are done correctly, from the plans stage through the finished product.

For more information about the features and benefits of ENERGY STAR Qualified New Homes, and to search for New Home "Partners" (builders, home energy raters, lenders, etc.), please call the EPA's ENERGY STAR Hotline, 1-888-STAR-YES or visit www.energystar.gov and follow links to "New Homes."

The Residential Energy Services Network (RESNET, www.natresnet.org) is another useful resource, providing more specific information about the Home Energy Rating System (HERS), energy codes and a directory of rating organizations.

3

House System

Moisture related failures, indoor air quality problems, combustion backdrafting, sooty "ghost" stains on walls and carpets, mold and mildew in homes—callbacks of these types have increased dramatically in recent years. They are often blamed on houses that are "over-insulated" or "too tight." Although these problems were unusual in the days when houses were leaky and uninsulated, they are not *caused* by these factors alone. In fact, it is rare to find a failure of this sort which is caused by any single factor. These problems are usually the result of the different components of the house interacting, as a system, in ways that were not foreseen by the builder.

Over the last century, the introduction of new materials such as plywood sheathing and housewraps has changed the way houses are built. Houses are tighter, and there are many more pollutants found inside, generated by the occupants and by the building materials themselves. As energy costs have risen, insulation has become a necessity. The advent of central heating systems with automatic controls has contributed to increased consumer demand for comfort in their homes, and heating systems have become more efficient. In addition to advances in building construction, consumer lifestyle changes have altered homeowners' expectations. People want houses that are larger and more complex, with more features than ever before. All of these things have an effect on each other, and on the operation of the house system.

It is becoming widely recognized that many of the failures and warranty callbacks in new houses are a result of mis-applying new technologies or materials—not because they were installed "wrong," but because nobody predicted the effect that a change in one area might have on some other part of the the house. Often, the complexities of a building make it difficult to find the source of a problem, even after it occurs. Consider the following example (a true story):

Building Failure Case Study

A homeowner calls in a building science specialist to help with a moisture problem during the heating season. The house has condensation and mold in the attic and living space. The specialist arrives at the property, and an interview of the client shows that this is an ongoing problem; in fact, it has gotten worse. The customer had previously consulted with several contractors and the local utility company, and was informed that the solution to the moisture in his attic was to add ventilation. When he asked how much ventilation to add, he was told, “You can’t over-ventilate an attic.” He was also warned that soffit vents would do him no good if they were blocked by insulation. So he installed extra soffit ventilation and pulled the insulation back from the eaves to allow free air flow. Since the hip roof did not have much ridge area, the homeowner installed two turbine vents to satisfy the need for upper ventilation.

On inspecting the house, the specialist finds the following:

- The roof sheathing is damp and spotted with mold.
- The roof has continuous soffit vents and two turbine vents.
- The fiberglass batts in the attic have been pulled away from the eaves approximately 18".
- There is black mold growing on the second floor ceilings in rectangular patterns around the house perimeter.
- The relative humidity in the living space is measured to be higher than normal for winter conditions.
- The bathroom exhaust fans are vented outdoors, but have a very low air flow rate and are rarely used.
- A blower door test confirms that the building is fairly tight, but there is still communication between the attic and the living space, by means of top plates and an open plumbing chase.
- The clothes dryer in the basement has a vent to outside, but the hose is disconnected.
- There is a piece of plywood in the basement loosely covering a sump, which leads to a small stream running underneath the building.

It is clear to the specialist what has happened. First, the turbine vents drew air not only through the soffit vents as intended, but also drew more air than ever from the house into the attic. With the high levels of humidity in the living space, combined with the fact that leaks into the attic had never been sealed, the turbines were moving moisture into the attic even more quickly than before. Second, in his effort to open up the soffit vents, the homeowner removed the insulation. This created a cold surface all around the perimeter of his upstairs ceiling for moisture to condense, and mold to grow on. No one thought to look in the basement when diagnosing the problem, but this is where the source of the moisture was lurking all the time.

The specialist wrote up a repair punch list as follows:

- Cover the sump in the basement with a gasketed cover to discourage the water from evaporating into the house.
- Re-connect the dryer hose.
- Seal leaks into the attic, to minimize the path for moisture to reach the attic.
- Replace the turbine vents with standard roof vents.
- Re-insulate the perimeter of the attic.
- Install baffles to allow free air movement through soffit vents and to direct the air over, rather than through, the insulation.
- Install a continuous running, low-level exhaust fan in one bathroom, to ensure the proper ventilation rate.

When the building was inspected the following year, the moisture was gone and the occupants were healthier and more comfortable.

Why did this building fail? The answer lies in the the fact that nobody evaluated how one aspect of the building's construction might affect another part of the building. Additionally, nobody evaluated the effects of occupant behavior on the performance of the building. When the foundation was built, it was noted that the underground water might cause flooding problems, so the decision was made to include a sump. When the framing, exterior shell, and interior finish were installed, each contractor took enough care that the building ended up with a relatively air-tight shell. But the builder did not realize that by doing these two things successfully, they had created a highway for moisture to pass through the interior wall cavities directly from basement to attic. Bathroom fans were installed and properly vented outside, but nobody predicted that the occupants wouldn't use them.

Why was the moisture problem mis-diagnosed? This is primarily because the contractors making the assessment took too narrow a view when evaluating the house. If a problem occurs in the attic, it is easy to assume that you will find the answer by looking in the attic. However, the house system is complex enough that this is often not the case.

The House as a System

When one component of the building fails, or is even out of tune, it can set off a chain reaction with unexpected results. To successfully avoid these kinds of failures, it is necessary to take a systems approach to the design and construction of buildings. Every trade may do its job properly, but if nobody is paying attention to the issues of moisture sources and ventilation, a house can end up with serious mold and mildew problems. Every aspect of a home may meet the required codes, but there can still be carbon monoxide spillage into the living space. The construction supervisor may do a fine job of managing all the subcontractors, but if no one considers the interactions of the individual parts of the building, or thinks about how the building will perform when occupied, all this hard work may be inadequate.

It is easy to look at the house as a collection of components: foundation, frame, mechanical services, drywall, trim, fixtures and finishes. But there is more to a building than this. Figure 3.1 shows a schematic of the house system with some of its interactions.

The first step to understanding the house system is to realize that the building structure itself, and the mechanical systems in it, interact with each other and with the people in the building. People turn thermostats up and down, they move switches and valves, they build walls, cut holes, and leave windows and doors open or closed. Both the building and the mechanical systems also interact with the immediate environment around the house: how cold or hot is it, which direction is the sun shining from, how much wind or rain. These environmental factors change the building directly, causing parts of it to get hot or cold, or to get wet, and to dry out; and they also affect how comfortable people are inside, causing them to act in different ways relative to the building.

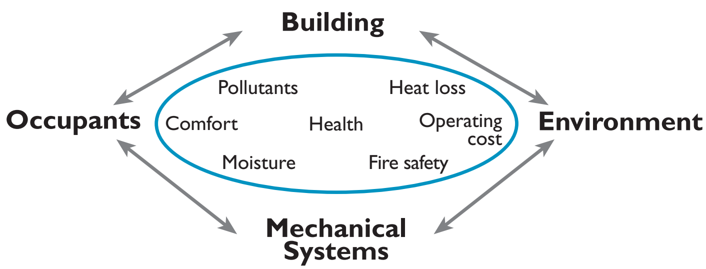
It is not necessary to make a study of every interaction that can happen in a building based on this concept. However, it is important for someone to take responsibility for the house as a whole system, and to think about common ways that the components in a house interact under everyday situations. It is imperative that house designers and general contractors learn the basics of the house as a system if they want to avoid these problems.

Fortunately, there has been much research in recent years and a growing body of field experience based on new construction, testing, weatherization and remediation work. Ice dams, indoor air quality problems, radon, nail pops in drywall, freezing pipes, combustion safety and backdrafting problems can all be reduced by understanding the basics of moisture and air movement. These effects can be understood on a level sufficient to avoid the most common problems, as long as someone is thinking past the individual parts and looking at the whole.

Going Further

This guide attempts to include details that are consistent with good building science as well as applicable codes. However, it is beyond the scope of this guide to address the subjects of moisture and air movement in much detail. Many of the sources listed in Appendix B contain excellent information on building science and house system interactions. The EEBA *Builder's Guide* has more detailed information on building failures, along with their causes and solutions.

FIGURE 3.1
The House as a System



A house is more than just a collection of parts. The structure and mechanical systems interact with the occupants, with each other, and with the immediate surroundings in numerous complex ways.

4

Designer

This chapter applies to architects, engineers and other professional designers, as well as to builders that do significant portions of their own design work.

Energy Code Requirements

As the designer of a new home, your primary responsibility for meeting the energy code is in specifying R-values of insulation, thermal performance of windows, and the efficiency of the heating system. Although you could simply design the home and leave the compliance analysis to the builder, a designer will often do the analysis with one of the design tools outlined on pages 4-6 to determine these values. There are two good reasons to do this:

- The thermal performance of various components will affect the detailing, for example the R-value of walls and cathedral ceilings affects their thickness.
- As the designer, it may be faster for you to calculate the square foot areas of the various components, and it may be easier to adjust the design based on energy code constraints.

Determining thermal envelope

Another important role the designer may take is to determine the boundaries of the thermal envelope of the house. This includes choices like whether to condition basements, where to put the insulation in some attic areas, and the like.

There are two types of basements: **conditioned** and **unconditioned**. If you are heating the basement on purpose (with air registers, baseboard, radiant slab, etc.), you must call it a conditioned basement. If you aren't heating the basement on purpose, it's your choice which type of basement to build. See Figures 4.1-4.2, and Chapter 6 for more detail on basement requirements. Similar choices exist for some types of attic areas, such as those shown in Figures 7.16-7.17.

Other hints

Specifying materials and equipment Glass with low U-factors, or heating systems with high AFUE ratings can make it easier to pass the code (see pages 61 and 69). Be sure you know what products are available and at what cost, just as you do with other materials you specify.

Allow some room in the compliance analysis. Whatever method of analysis you choose, it's a good idea to give yourself a margin of safety in complying. That way, if the client decides to add a window during the construction process, the house is more likely to remain compliant.

ENERGY STAR

Because ENERGY STAR is a performance-based standard, there are many ways to trade off better performance in some areas with less performance in others. It is also possible to take credit for some things that the code does not recognize. Here are some tips that may help you during the design process to build a home that earns the ENERGY STAR label, with a minimum of added cost:

- **Orientation—**Solar heat gain from south-facing windows reduces the annual heating load and makes homes more comfortable. Think about how you might take advantage of this while working within the site and other design constraints. For example, even if there's a great view to the east or west, you might be able to "flip" the design over to put the garage on the north side and expose more windows to the south, without adding any cost. Note also that most unwanted heat gain in the summer comes from east- and west-facing windows; if there's a compelling reason to put a lot of glass on the west or east side of a house, consider using a "southern" low-e type of glass with a low solar heat gain coefficient on that side(s), or shading the glass with adequate overhangs.
- **Insulation material—**Some types of insulation, such as dense-packed or damp-spray cellulose, or spray foams, fill cavities completely, help to reduce air leakage, and add more R-value in the same sized framing cavity. Rigid foam applied to the exterior walls or ceiling adds R-value, reduces the thermal "bridge" of the framing, and can form a good air barrier if the seams are taped. Think about specifying some of these materials to improve the performance of the building.
- **Allow space for mechanicals—**Some of the worst energy users include undersized, underinsulated, leaky ductwork, especially when located in unconditioned spaces. As the designer, you have

little control of the quality of mechanical installations, but you can influence their placement. Duct leaks that occur outside the thermal envelope can cause thermal, comfort, moisture and backdrafting problems. If you specify all ductwork to be entirely within the thermal envelope, the consequences of leaks are greatly reduced. Building frames that have room for mechanical equipment and chases for ductwork are less likely to have undersized and torturous duct runs. Consider planning the space requirements for the mechanical systems and specifying them on the plans.

Energy Page

Because you are putting the design of the home on paper, consider adding a separate "Energy Page" to the blueprints. Include a table of gross and net square feet of walls, ceilings, windows, doors, floors, etc. and the specifications for their thermal performance including insulation R-values, fenestration U-factors, and mechanical equipment efficiency ratings. Also include detail drawings of insulation baffles, duct terminations, foundation insulation, air sealing details, and the like. If you are also conducting the energy code compliance analysis, please indicate on this page which compliance path you used.

Going Further

Tradeoffs

Heating and cooling systems tend to be substantially oversized, even in conventionally built houses. If the HVAC installer uses the same rules of thumb to size equipment for an efficient house, they will be even more oversized. Oversized equipment costs more to install and to operate. You can save money on a project by sizing the heating and cooling systems properly (both equipment and distribution systems), and this savings can help pay for the upgrades to the building shell.

You can also get "payoffs" by doing some or all of the following:

- Use direct-vent or sealed combustion heating and hot water equipment and save the cost. Never use unvented combustion equipment (see page 75).
- Use exterior foam sheathing as a drainage plane, as well as part of the wall insulation R-value.
- Use drywall returns around windows (see Figure 8.4).
- Specify advanced framing techniques (see pages 44-53).
- Structural insulated panels, precast foundation sections or stay-in-place insulating formwork may cost more initially, but may provide labor savings and multiple benefits to the building's structure and function for little or no net cost.

- Many electric and gas utilities have rebates for high-efficiency heating or heating/cooling equipment, which help offset the added cost of the equipment.

Siting
Site selection, preparation, and landscaping all have effects on the energy use of a building as well as on moisture, drainage and occupant comfort.

Material Selection
It is important to select materials that perform their intended function, and minimize the risk to the building occupants. Ventilation systems are good for people, because they provide fresh air and dilute toxins. However, it's always better to reduce a toxin than to dilute it with ventilation. Many materials that are found in new construction have varying degrees of toxicity, and it is important to consider using those with the least risk of exposure to the occupants.

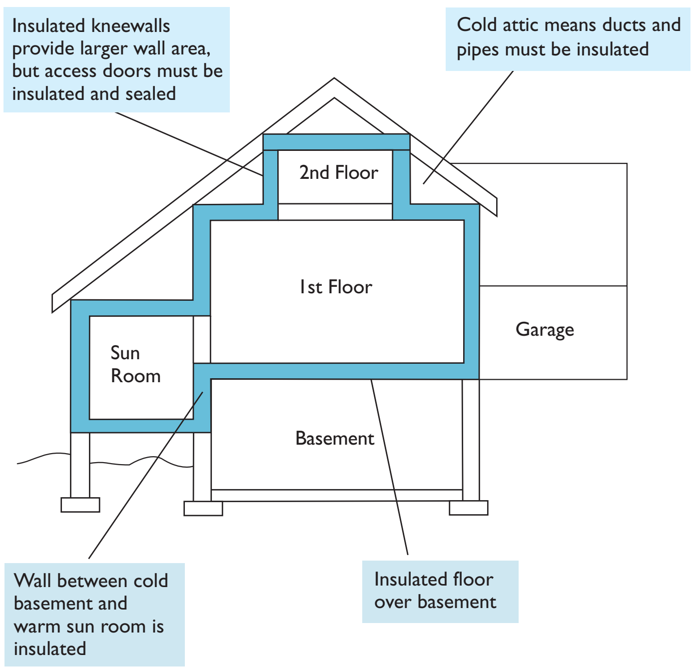
Appliances
Although the buyer usually has much control over appliance selection, the designer often has influence as well. Many appliances are available that have the ENERGY STAR label, indicating a high level of energy efficiency. Utility rebates may also be available for some ENERGY STAR labeled appliances. The internet address for ENERGY STAR labeled appliances is found in Appendix B. You should also think about house depressurization, combustion safety, as well as customer convenience.

Commissioning*
"Commissioning" is the testing of the home's mechanical systems and other subsystems for intended operation. Although commercial construction may include a commissioning process, most houses never get tested. For each ENERGY STAR Qualified Home, tests of building air leakage and duct leakage will be conducted as part of the certification process. In addition, every house should have combustion safety tests of venting systems and carbon monoxide for every combustion appliance (except sealed combustion systems).

*A sampling protocol can be implemented using the HERS or BOP verification method and is intended for builders who have demonstrated a consistency in their specifications and production processes. The sampling protocol allows HERS raters (or 3rd party verifiers) to randomly test and inspect a minimum of 15 percent of homes from a batch of homes located within the same climate region (typically the same subdivision). It is intended to minimize production interruptions and rating/verification production costs while ensuring homes meet or exceed the criteria for qualifying homes as ENERGY STAR. Go to www.energystar.gov/homes for additional details.

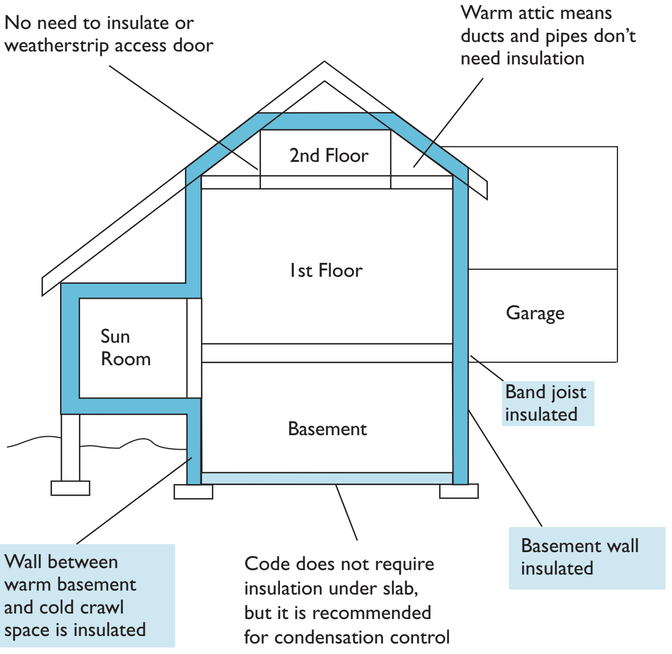
Good design is important for good buildings, but good design does not guarantee good buildings. Many building plans are drawn with exemplary construction details, and those details are ignored, botched, replaced, or "value engineered" out before or during the construction process. Designers do not always have the authority to ensure good details are followed during the construction process. A home energy rater or other energy consultant can act as an independent third party to point out some things that may go wrong in the construction process.

FIGURE 4.1
Typical cape with unconditioned basement



This is a schematic of a cape style house with an unconditioned basement and unheated kneewall areas.

FIGURE 4.2
Cape with conditioned basement and insulated rafters



This schematic shows the same cape style house with a heated basement and kneewall areas. Note that the two choices are independent of each other, it is possible to have heated kneewall attics with an unheated basement, or the reverse.

5

Builder/General Contractor

General Contractor

General contractors have a tough job. Faced with the challenges of managing project budgets, scheduling and dealing with subcontractors, clients, architects, building officials, and the weather, it's no wonder energy and building science tend to be a low priority for most builders. Energy efficiency is difficult to see, and many buyers assume that all new homes are energy-efficient. And after all, the insulation and HVAC contractors are supposed to do their jobs properly, aren't they? Unfortunately, the general contractor is straight in the line of fire when it comes to interpreting the construction documents, and producing a building that works properly, wears well, doesn't suffer moisture damage, and is inexpensive to maintain.

Building energy-efficient homes can provide several benefits to large and small builders. In addition to the marketing support provided by EPA for ENERGY STAR Qualified New Homes, builders who pay attention to the house as a system can reduce their warranty costs, improve customer satisfaction and referrals, and increase their profits. To build a house right takes time and attention to details, and substantial understanding of the reasons we do things the way that we do. It takes diligence in dealing with tradespeople; training them in what we want done, and why, is critical. The reward is a high level of confidence in dealing with clients, in saying "this product is superior to the competition." You can sell these superior features on their merits. Some builders offer energy bill guarantees. Others provide checklists for prospects to take with them when they look at the competition: "Here are 25 things we do to ensure your home will be safe, comfortable, efficient, and durable. See how many other builders do all of these things!

Builder/Designers

Many houses are built without the involvement of an architect or designer. Usually there is no budget for a designer. Sometimes the builder uses prepared or traditional designs. Sometimes the builder is the designer. In all of these cases, or if the designer on a project is inaccessible or uninterested in the subject matter of this guide, it may be useful for the builder to read Chapter 4 as well as Chapter 5.

Energy Code Requirements

In order to meet the energy code, the builder needs to know the energy-related specifications for the entire project. This means not only understanding the thermal performance specifications that are submitted along with the permit application, but also all of the General Requirements (see page 4). These energy requirements affect the work of many of the subs on the job, so the general contractor has to keep track of all of these requirements. It is a good idea to be familiar with all the material in this guide, as well as the IECC, so you are not surprised.

ENERGY STAR

The same skills required to meet the energy code are useful in building an ENERGY STAR Qualified New Home. Learn to communicate with your subcontractors about energy requirements, and coordinate them with an eye on the whole picture. Refer to Chapters 3 and 4.

Building homes with a systems approach may require some adjustments to your typical construction sequence. For example, you may ask framers to seal leaks with caulking, construction adhesive, or gaskets; to install exterior foam insulation; or to install draftstops in key areas. You will need to insulate and air seal shower or bathtub units on exterior walls before the plumber hooks them up. You may need to coordinate framers to allow the proper room for mechanical installations. Look at the other sections in this manual, look at the EEBA *Builder's Guide*, determine what details you want to use, and pass that information along to the various subcontractors.

Going Further

The EEBA *Builder's Guide* has a chapter that covers issues facing a general contractor. The remainder of the EEBA *Builder's Guide*, as well as many of the other resources listed in Appendix B, are also useful sources of information about house as a system, moisture, drainage, energy, air pressure, combustion safety, and other topics.

6

Foundation

Foundation Moisture

Aside from structural concerns, the most important consideration for foundation design is moisture. No client wants a wet basement. No client wants a damp basement. No client wants mold in their basement. The best way to ensure that a foundation stays dry most of the time is to include:

- Proper drainage
- Capillary breaks

You can't go back to add these later (for a reasonable cost) so the time to do it is when you build the foundation (see Figure 6.1). This applies to full foundations, to crawlspaces, and to slab-on-grade construction.

Even with these precautions, the foundation walls may still be damp at times. You can't guarantee that mold won't grow. You *can* minimize the potential for conditions that foster mold growth, and maximize the potential for walls to dry when they do get wet. Although the code calls for a vapor retarder on the interior (warm in winter) side of insulated foundation walls, a vapor retarder is **not** recommended on either side of the wall, to facilitate drying. The figures in this chapter show several possibilities for relatively forgiving, mold-resistant, insulated basement wall assemblies. If the proper drainage and capillary breaks are not present, it is better **not** to build a conditioned basement so that the foundation walls do not need insulating.

Energy Code Requirements

All basement spaces must be defined as "conditioned" or "unconditioned." See page 21, and Figures 4.1-4.2.

Conditioned Basements

In a conditioned basement, you must:

- Insulate the foundation walls on the inside or the outside of the wall. The required R-value depends on the results of your compliance analysis.
- Insulation must extend from the top of the wall to the basement floor (IECC 502.2.1.6,502.2.3.6, 602.1.5).
- Insulate the band joist of the floor framing above the basement.
- Seal air leaks in the foundation walls and slab floor, as well as the sill / band joist area.
- If the foundation is insulated with rigid foam on the exterior, the insulation must be protected with a rigid, opaque and weather-resistant barrier that extends at least 6" below grade (IECC 102.4.1).

Important note: When you are doing compliance analysis on a conditioned basement, you must look at each basement wall separately and determine, wall by wall, whether the wall is more than 50% above grade or more than 50% below grade. Walls that are 50% or more above grade, must be added in with above grade walls in your calculations, and insulated to the same R-value. Walls that are more than 50% below grade are treated as "basement walls."

Unconditioned Basements

In an unconditioned basement, you must:

- Insulate the floor above the basement. The required R-value depends on the results of your compliance analysis.
- Insulate the stairwell between the basement and conditioned first floor.
- Insulate heating pipes and air ducts in the basement.
- Seal the ducts in the basement.
- Seal air leaks in the floor system between the basement and the first floor, such as wiring and plumbing penetrations, and weatherstripping on the basement door. Include the basement door in your calculations.

Slab-on-grade

Slab perimeter (edge) insulation must be installed where the slab is part of the conditioned space of the house. This includes a slab-on-grade house or addition, the walkout portion of a heated basement, or a breezeway that shares a slab with the garage.

Slab perimeters must be insulated where the top edge of the slab is above grade, or less than one foot below grade (see Figure 6.6). The R-value to use depends on the results of your compliance analysis. If the slab edge insulation is on the exterior, the insulation must be protected with a rigid, opaque and weather-resistant barrier that extends at least 6" below grade (IECC 102.4.1).

Slab perimeter insulation must run all the way to the top of the slab. It may go down, or down and across, for a total of 24" (climates less than 6000 HDD) or a total of 48" (climates more than 6000 HDD). If you are using the IECC Chapter 6 tables, 48" slab insulation is required in climates over 5,500 HDD according to Table 602.1. See Figures 6.7-6.8 for examples.

Note: "Heating Degree Days" (HDD) are a measure of how severe the heating season is. With the exception of Garrett County, all of Maryland has a climate of less than 6,000 HDD.

Crawlspace

The floor over a vented crawlspace construction must be insulated to the same R-value as a floor over an unconditioned basement, according to the compliance analysis. The walls of an unvented crawlspace must be insulated according to the R-value shown in the compliance analysis for "crawlspace walls."

ENERGY STAR

To meet the ENERGY STAR performance guidelines, you may need to put slightly more insulation in your basement walls (or the floor over the basement) than you would to meet the code. Other recommendations:

- Install at least 4" of uniform sized, washed stone underneath the slab floor. This acts as a capillary break to help prevent absorption of ground moisture. It also makes it easy to add a sub-slab ventilation system for radon mitigation, if radon is found after construction (see page 114).
- Insulate basement slabs, even in unheated basements. 1" of rigid polystyrene foam under the slab will keep it warmer in summer and reduce the chance of condensation which can wet the slab and lead to mold and mildew. This will also improve comfort and reduce moisture problems if the basement is finished off later.
- Do not install carpeting on below-grade slab floors unless the slab is insulated under its entire area, and the foundation is well drained. Moisture from condensation on an uninsulated slab, or drawn up by capillary action can lead to hidden mold and mildew problems in carpets.
- Always insulate under the entire surface of radiant heated slabs, even though the code does not require it. Most radiant equipment manufacturers specify insulation under the slab; if you are heating the slab, the insulation will reduce heat loss and improve comfort. Because of the high temperature of radiant heated slabs, a minimum of R-15 rigid insulation is suggested even though manufacturers may recommend less.

- Try to avoid crawlspaces. Where you do build over a crawlspace, be certain that the vapor retarder on the crawlspace floor is completely sealed at all seams and penetrations, and sealed to the wall.

Conditioned or Unconditioned?
The choice of whether to insulate the basement is yours, unless you have an intentional heat supply. There are several reasons for and against constructing a conditioned basement space:

- People often want to use basements. Even if they are not finished space, people often use basements for laundry, projects, storage or other uses. They really don't want the basement to be a very cold space in winter. If they do finish off the space later, it will be easier if the basement is already insulated.
- It's easier to air seal the foundation walls. Floors are usually far leakier than foundation walls, and are also harder to seal.
- There's no need to insulate HVAC ducts or pipes in a conditioned basement, which can save money.
- Warm basements are less likely to have condensation and related mold and mildew problems than cold basements.
- Insulating foundation walls has potential pitfalls. Exterior insulation may provide pathways for insects, must be protected, and tied in somehow with the wall above. Interior insulation cools foundation walls, and if drainage and insulation details are not built carefully there is substantial risk of condensation and mold growth.
- Insulating walls often costs more than insulating the floor over a basement.

Going Further

Other issues to think carefully about when planning foundation details include:

- **Concrete movement** and cracking can result in callbacks, air leaks and water entry in foundations. The EEBA *Builder's Guide* includes a discussion of concrete movement and control joints—which can reduce or eliminate these problems—as well as other foundation issues.
- **Moisture, drainage and capillary breaks—**Foundations are built in the ground. Depending on where you build, the ground is either sometimes wet or always wet. All foundations should be built with good drainage and moisture protection.
- **Insect entry—**Termites and carpenter ants can tunnel through rigid foam insulation. If the foam insulation is between the ground and the wood frame of the house, they can use it as a way to get to the wood without being seen. For this reason some model codes have prohibited the use of foam insulation above grade in termite-

prone areas. While the Northeastern and mid-Atlantic states are not generally considered to be termite-prone, termite protection still warrants consideration.

Termites don't eat foam board, but they will eat wood, causing structural damage. Carpenter ants don't eat either one, but they will nest in both and over long periods can cause structural damage.

There may be ways to effectively block insect entry from foam board to adjoining wood framing (or above grade foam sheathing); however, the details for such a system must be implemented very carefully. The energy code (and common sense) requires insulation in heated basements to the top of the foundation wall; after all, most heat loss occurs where the foundation wall is exposed above grade. You can't cut exterior foam board off at grade, so it may be better to insulate conditioned basements on the inside of foundation walls than to attempt an insect barrier between exterior foam and the wood framing.

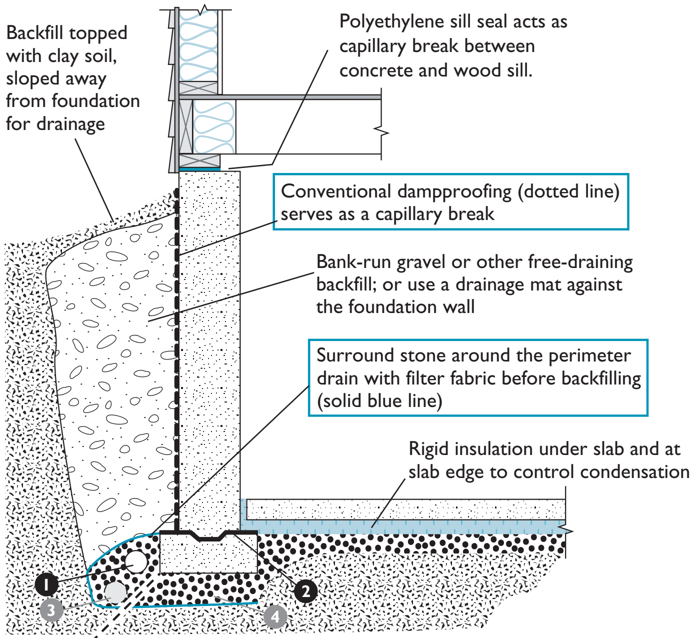
- **Alternative foundation systems—**such as insulated concrete forms (ICFs) or precast concrete walls can speed up the construction process (especially in the winter) and provide a pre-insulated, airtight assembly. They can be very cost-effective, when compared to a poured concrete wall with a built-up insulated stud wall.

- **Crawlspaces—**Historically, many building codes have required passive vents in exterior walls and minimal vapor barrier protection for crawlspace floors. While this strategy may have helped to reduce moisture loads at times, it also introduced moisture in the summer when outdoor air is more humid than the cool crawlspace. Building science has shown that ventilating crawlspaces often does more harm than good, and codes are starting to catch up with the more sensible approach of building a tight crawlspace with good drainage and vapor control. In fact, national model energy codes are beginning to include exceptions that allow for unvented crawlspaces that are either vented to the interior, conditioned, or provide air to the return side of a heat and/or air conditioning system (IRC R408.3).

Basically a crawlspace should be built like a very short, conditioned basement (see Figure 6.9). There are three critical elements to consider: adequate footage drainage, thorough vapor barrier installation, and insulated walls. The vapor barrier should be at least 6 mils thick, and all seams must be sealed with a good quality tape (like 3M contractor's tape or Tyvek sheathing tape) or acoustical sealant. It should be mechanically fastened to the exterior walls, and all penetrations (including piers) must be sealed. Like any basement, it's important to keep inside air away from the foundation wall to prevent condensation.

FIGURE 6.1

Foundation moisture control*



1. Perforated drain pipe at footing level, drains downhill to daylight or to sump pit inside basement
2. Dampproofing or cement-based waterproofing applied to top of footing as capillary break between footing and wall (dark line)

Alternate Strategy—#3 and 4—more effective, where allowed by local codes. Note: the footing drain can only be installed below the footing level if the footing is completely supported by uniform sized washed stone, which is noncompressible. When in doubt about the bearing capacity of the underlying soil, consult a soils engineer.

3. Drain pipe installed below footing level (and beyond load bearing range of stone, as indicated by dotted line) to carry water away from footing
4. 4-6" *washed, uniform sized* stone (1/2" – 1 1/2") under footing provides capillary break and drainage.

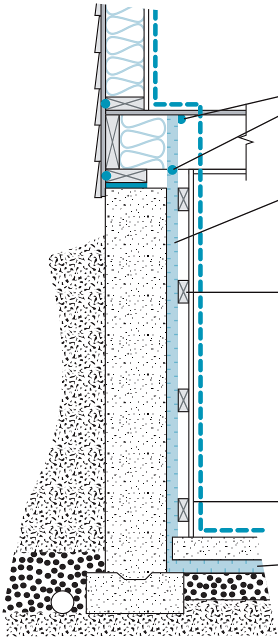
CAUTION: The stone surrounding the perimeter drain, under the slab and/or under footing must be uniform in size and washed (with no fine grains), to prevent settling or undermining.

TIP: One inch of rigid foam insulation under the slab will reduce the potential for condensation in the summer. Even if the basement is not finished space, condensation on the slab can contribute to moisture problems in the home.

***Note: *All* full and crawlspace foundations should incorporate these details.**

FIGURE 6.2

Conditioned basement with interior rigid foam

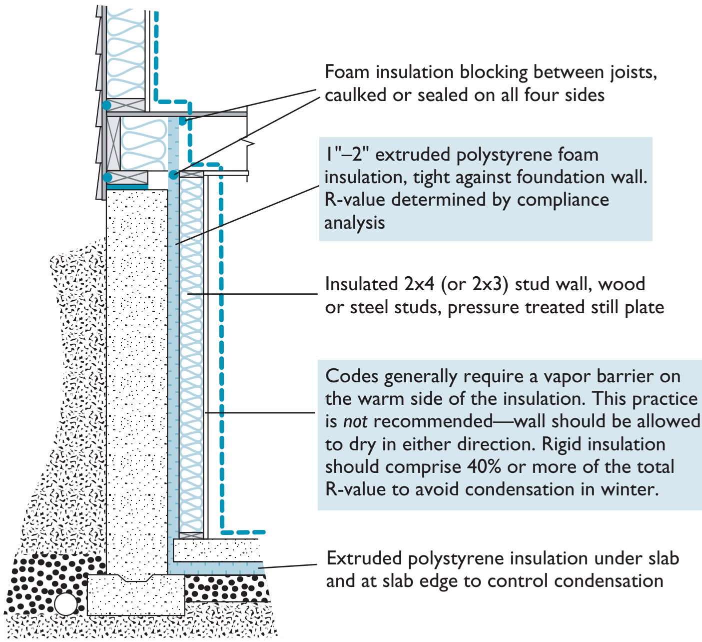


CAUTION: All vertical and horizontal joints in the insulation must be carefully sealed to prevent humid basement air from reaching the cool foundation wall, where it can condense.

TIP: Glass-faced gypsum board or cement "tile-backer" board is much less vulnerable to moisture than paper-faced drywall. It can be finished with the veneer (skim-coat) plaster. Use vinyl or fiber-cement components for baseboard trim.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 6.1.

FIGURE 6.3
Conditioned basement with interior stud wall



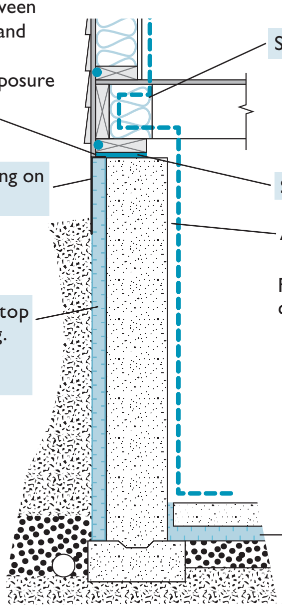
CAUTION: All vertical and horizontal joints in the rigid insulation must be carefully sealed to prevent humid basement air from reaching the cool foundation wall, where it can condense.

TIP: Glass-faced gypsum board or cement "tile-backer" board is much less vulnerable to moisture than paper-faced drywall. It can be finished with the veneer (skim-coat) plaster. Use vinyl or fiber-cement components for baseboard trim.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 6.1.

FIGURE 6.4

Basement with exterior rigid foam

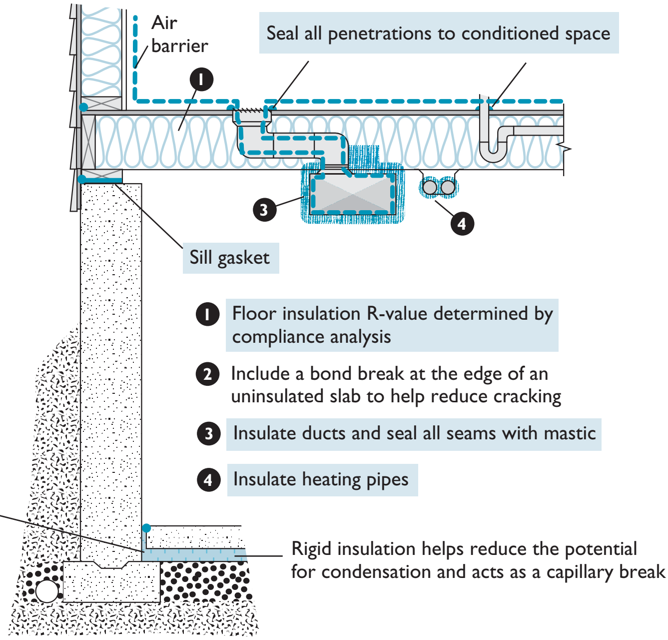


CAUTION: Exterior foam insulation may provide a pathway for termites and carpenter ants to reach framing. See page 32.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 6.1.

FIGURE 6.5

Unconditioned basement



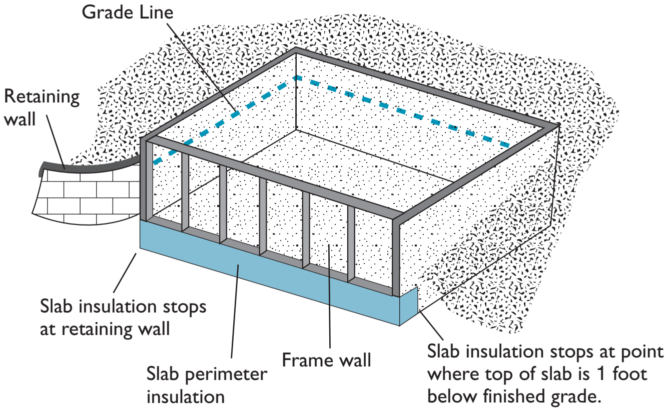
TIP: One inch of rigid foam insulation under the slab will reduce the potential for condensation in the summer (see Figure 6.2). Even if the basement is not finished space, condensation on the slab can contribute to moisture problems in the home.

If conditioned space is adjacent to an unconditioned basement, then the wall between these two spaces must be insulated according to results of the compliance analysis.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 6.1.

FIGURE 6.6

Slab edge insulation, walkout basement



This is a view of a basement with a frame wall on one side, showing the placement of slab perimeter insulation.

FIGURE 6.7

Slab on grade with interior insulation

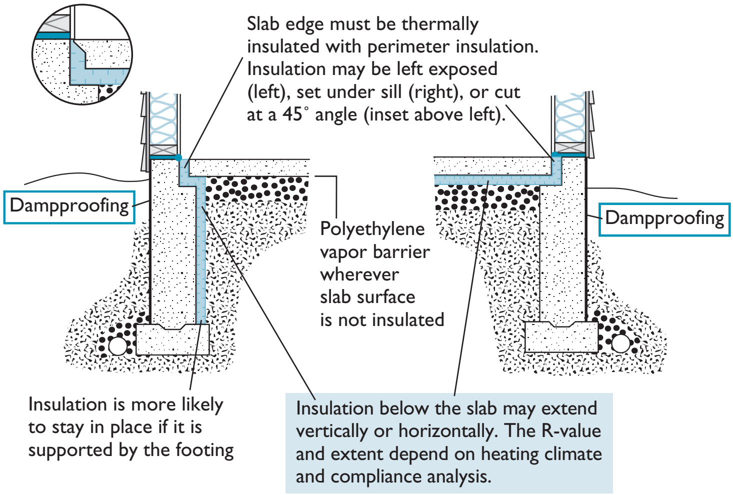
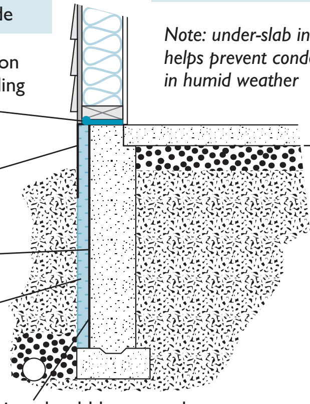


FIGURE 6.8

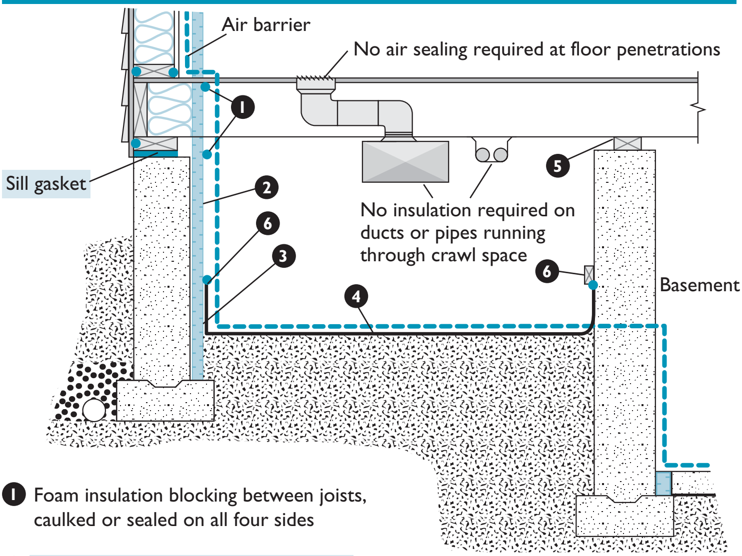
Slab on grade with exterior insulation



CAUTION: Exterior foam insulation may provide a pathway for termites and carpenter ants to reach framing. See page 32.

FIGURE 6.9

Conditioned, unvented crawl space with interior insulation (see page 33)



1. Foam insulation blocking between joists, caulked or sealed on all four sides
2. Insulation must be in substantial contact with wall, with no gaps between pieces. It must extend to the top of the wall.
3. If the crawlspace floor is 12" or more below the outside grade, the insulation must extend at least to the crawlspace floor. If the crawlspace floor is less than 12" below outside grade, the insulation must extend to the top of the footing (IECC 502.2.3.5).
4. A minimum 4-mil thick polyethylene vapor retarder is required by most codes. It is highly recommended to install 6-mil or laminated poly, lapped 12" and taped at all seams, and mechanically fastened and sealed to all walls, piers, columns, and service penetrations
5. No air sealing or insulation needed next to conditioned spaces
6. Extend vapor retarder 12" up walls and columns, and attach with nailer and adhesive

TIP: To avoid moisture problems in crawlspaces, install the same drainage and capillary breaks as for a full basement (see Figure 6.1).

Foundation drainage and capillary break details not shown for clarity—refer to Figure 6.1.

7

Framing

Energy Code Requirements

- **R-values of insulation—**The R-values determined from your compliance analysis can affect the dimensions of framing lumber you use. For example, an R-19 wall would often be built with 2x6 wall studs. However, there is almost always an alternative. For example, an R-19 wall can also be built with 2x4 studs, R-13 insulation and 1.5" of polystyrene foam board (R-6).
- **Air sealing details—**Most air sealing details can be carried out at any point up until the insulation and drywall are installed. However, many are much easier to implement during framing. Some of these critical details include band joist/sill areas, housewrap details (if housewrap is used as an air barrier), dropped soffit areas, draftstop blocking between wall and roof or wall and floor assemblies, etc. Detail drawings showing appropriate air sealing of these areas are shown in Figures 7.1, 7.2, 7.8, and 7.11-7.18.
- **Raised truss construction** or equivalent roof framing. This type of construction gives you some credit in the code compliance analysis, and also performs better. Examples of raised truss equivalents are shown in Figures 12.5-12.7.

ENERGY STAR

To meet the ENERGY STAR performance guidelines, you may need slightly more insulation R-value in the walls or ceiling than you would just to meet the code, and you may have to pay more attention to the air sealing details as well. However, there are some techniques you can use to help pay for these upgrades without compromising the structure of the building. Here are some suggestions:

- Use details that need less wood and leave more room for insulation, at exterior wall corners, partition wall intersections, headers, and the like. See Figures 7.4-7.7. The EEBA *Builder's Guide* has a section on framing with detail drawings showing additional options.
- Housewraps have been marketed for years as air barriers, but their primary purpose and benefit is as a drainage layer behind the exterior cladding. No siding and flashing system is completely waterproof, so a dependable drainage plane under sidings is needed as a secondary line of defense. Appropriate counter-flashing details are critical, and a vented rain screen can provide the best performance for keeping water out of the building. Housewrap, properly installed and sealed with tape, can contribute slightly to the air tightness of a building, but does nothing to slow down air leakage in most large leaks, which are located in basements and attics.

  In addition, plastic housewraps may be incompatible with unprimed cedar and redwood, and with cement stucco materials; and perforated plastic housewraps have been shown to leak water much more rapidly than unperforated plastics or felt paper. Felt paper or building paper may be a good alternative as a drainage plane. The EEBA *Builder's Guide* has in-depth discussions about rain drainage planes and air flow retarder systems.
- Try to discuss HVAC layouts with mechanical subcontractors before framing. If you can adjust framing to allow space for ducts and pipes, layouts can be more efficient and less costly, and less damage will be done to the frame during installation. For example, if a long center wall in a two-story house is framed with 2x6 studs, duct risers can be easily installed for floor registers in the upper story. Be sure to align floor framing with wall studs. At the very least, be sure that adequate mechanical chases exist. This type of approach can save on duct installation costs. The EEBA *Builder's Guide* section on design has more ideas related to HVAC integration.
- Consider sealing air leaks in the exterior of the walls as well as the interior. Two air barriers are better than one air barrier. Exterior air barriers help keep cold out and help prevent wind-washing of the cavity insulation, and they are easy to install (see the EEBA *Builder's Guide* section on air barriers).

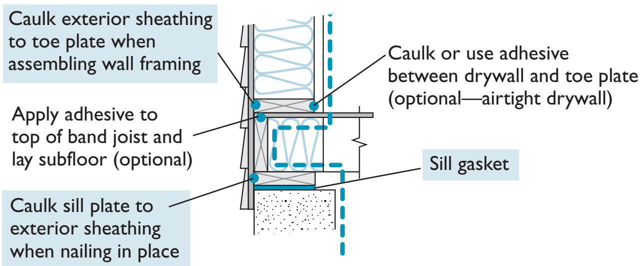
Going Further

Use advanced framing techniques that allow you to use less wood in the frame of the building, leaving more room for insulation and more room in the budget (see Figures 7.9-7.10). You can choose to use some of these techniques and not others; but you do have to think about how to apply these details. For example, don't use single top plates unless you "stack" roof, wall and floor framing. Don't use a single stud at the rough opening unless you hold the header up with hangers rated for the load. When they are applied properly, these techniques meet codes and work well. For more detail on advanced framing (sometimes called "Optimum Value Engineering") see *Cost Effective Home Building: A Design and Construction Handbook* by NAHB (contact information in Appendix B).

Think about the ways in which framing affects the installation of an effective rain control system (roofing, siding, trim, flashing, etc.), and an effective water vapor control system (vapor retarders, roof ventilation, etc.). For example, roof framing has a direct impact on the effectiveness of various roof ventilation strategies. See the EEBA *Builder's Guide* for more on rain control, framing details for moisture control, insulation, sheathings and vapor diffusion retarders.

FIGURE 7.1

Sealing band joists during framing

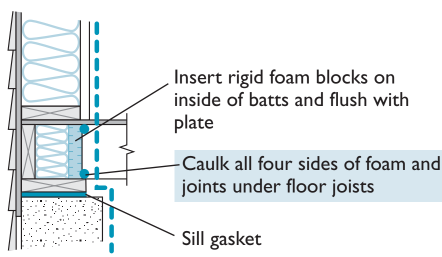


Remember to caulk or tape vertical seams between sheathing panels.

TIP: For better results, also use construction adhesive when setting the band joist on the sill.

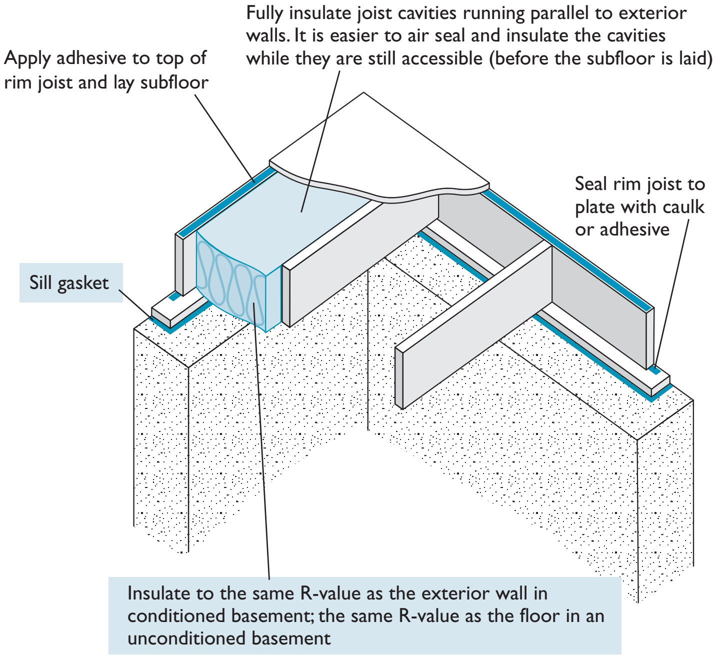
FIGURE 7.2

Sealing band joists after framing (alternate method)



Sealing the band joist is easiest to do during framing, but if it is missed at that time, this technique works well also.

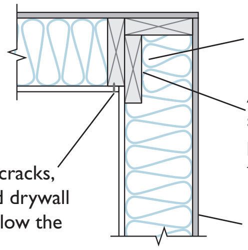
FIGURE 7.3
Sealing and insulating band joists during framing

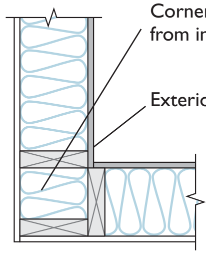


TIP: If you use a blown-in or sprayed insulation such as icynene, blown-in cellulose or fiberglass, or a similar system, this area can usually be insulated with the rest of the house.

Insulating the band joist after the floor sheathing is installed can be very difficult, depending on the joist layout. Care must be taken to keep insulation dry when installed during framing.

FIGURE 7.4
Insulated three-stud corners

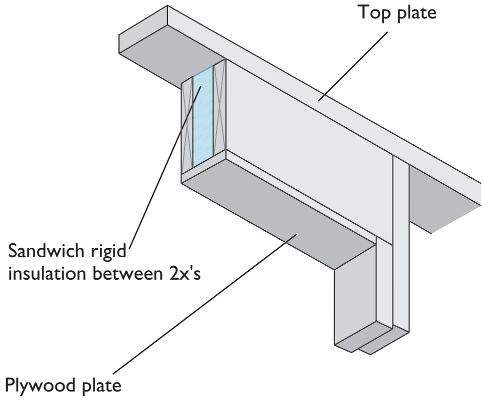




Conventionally framed corners are difficult to insulate and use more wood than insulated three-stud corners. For more savings and reduced drywall cracking, use clips for drywall backing at outside corners instead of the third stud.

FIGURE 7.5

Insulated header in a 2x6 wall

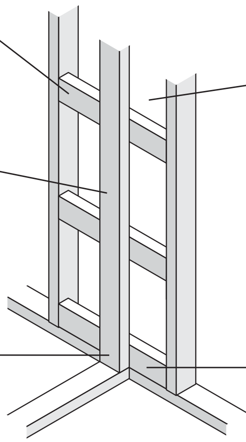


TIP: Use a few standard header sizes that will work in several locations. There is no need to size all headers equally.

As an alternative, insulated headers pre-manufactured from engineered wood I-beams and rigid foam may be used. Follow manufacturer's instructions regarding acceptable loading, span and support.

FIGURE 7.6

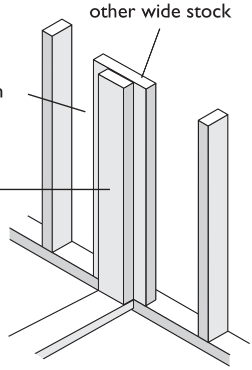
Ladder blocking for interior partition walls



Conventional box channels for partition walls are difficult to insulate. Ladder blocking (or vertical backing, Figure 7.7) use less wood, are easier to insulate, and are easier for electricians as well. See Figure 11.3 for air sealing details.

FIGURE 7.7

Drywall backing for interior partition walls



Vertical nailing stock can also be replaced by drywall clips to support drywall.

FIGURE 7.8

Cavity sealing example: chase on exterior wall

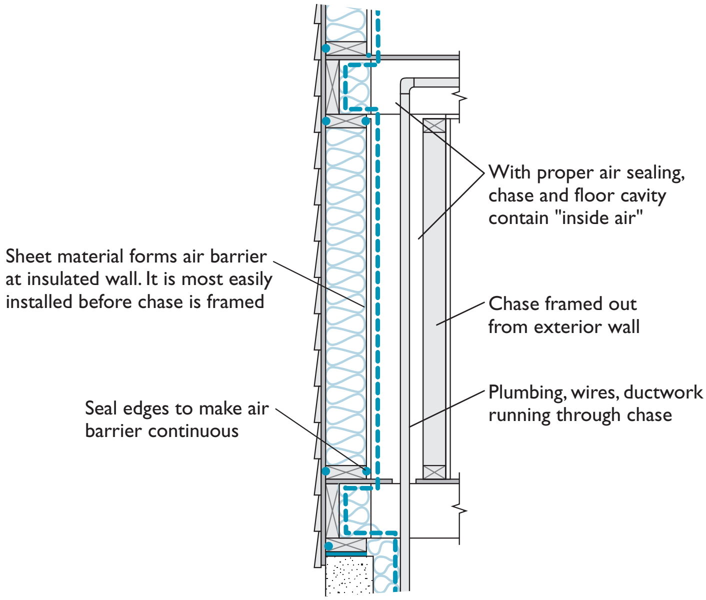
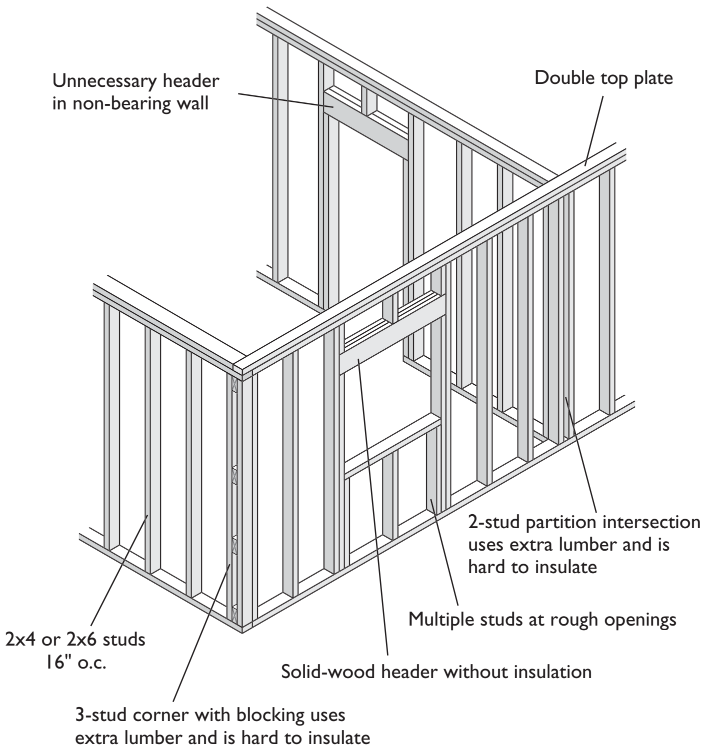


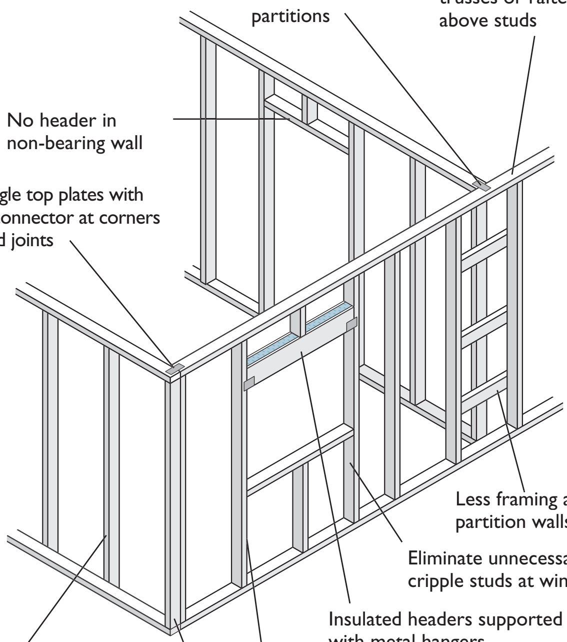
FIGURE 7.9

Conventional framing



Conventional framing techniques use unnecessary wood and leave less room for insulation. Advanced framing techniques are tested and proven by the National Association of Home Builders, and meet structural codes. For more detail on advanced framing (sometimes called “Optimum Value Engineering”) see *Cost Effective Home Building: A Design and Construction Handbook* by NAHB (contact information in Appendix B).

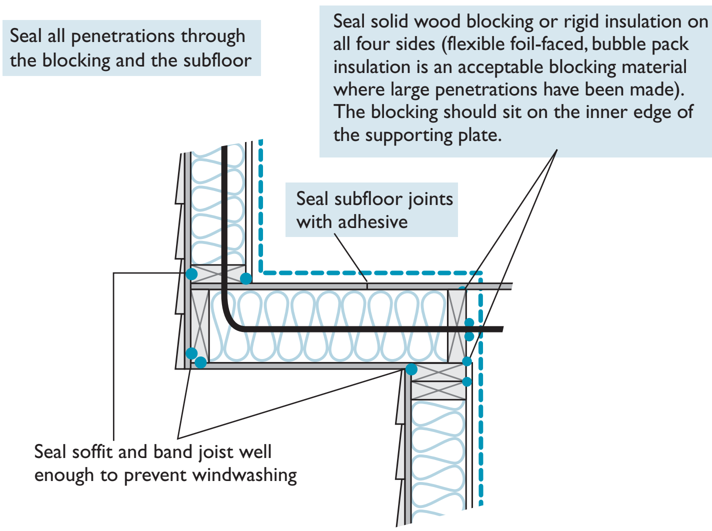
FIGURE 7.10
Advanced framing



Advanced framing uses up to 25% less wood, increases overall insulation R-values by 5 to 10%, and costs less to build. Most of these techniques can be used even when framing at 16" on center.

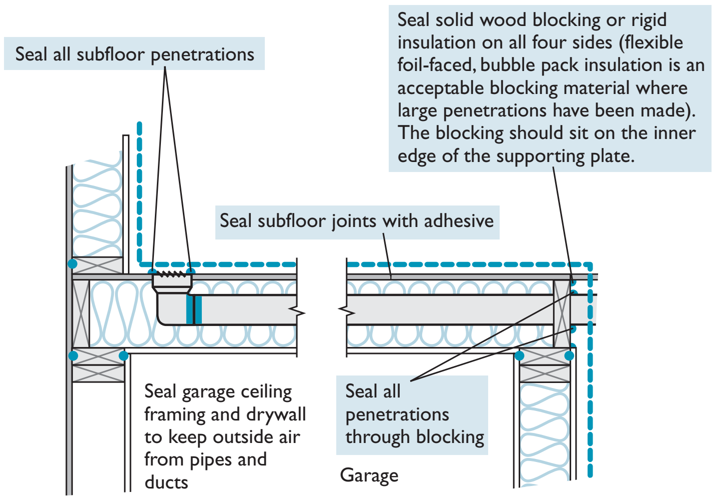
CAUTION: Code requires stack framing (structural support members are all aligned vertically) and metal splice plates to be used with single top plates.

FIGURE 7.11
Exterior cantilever floor with interior air sealing



CAUTION: Blocking is often pushed out by subcontractors. Encourage subs to make slightly oversized holes in blocking which are easier to seal later, rather than removing the entire piece.

FIGURE 7.12
Tuck-under garage



Tuck-under garages and attached garages are especially important to seal and isolate from the rest of the house, not only because of heat loss but also for health and safety reasons. Air leakage paths from a garage into the house can bring car exhaust, fumes from stored gasoline or other dangerous chemicals, or fire from the garage into the house. The floor over a garage is also a common area for freezing pipes and poor heat distribution. Provide both an interior and exterior air barrier to thoroughly isolate the floor system and reduce these potential problems.

FIGURE 7.13

Dropped soffit on interior wall

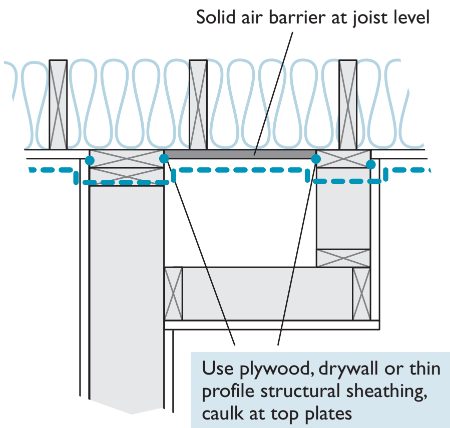
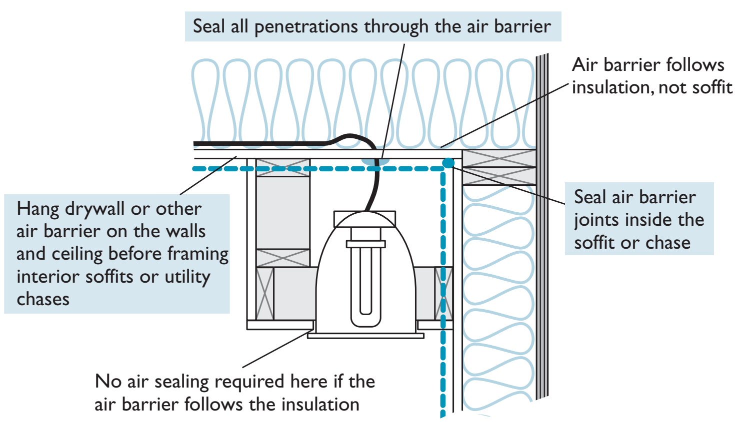


FIGURE 7.14

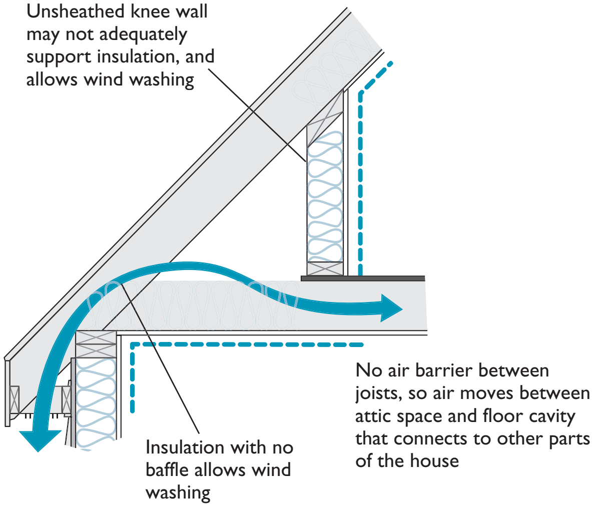
Interior soffit on exterior wall



Dropped soffits are commonly built with direct air paths from inside interior walls into attics. When recessed lights are installed, heat from the lights drives air leakage even faster. Installing air barriers before framing the soffit requires coordination of framing crews and materials.

FIGURE 7.15

Typical 1½-story knee wall



Typical knee wall details that are found in cape style homes, bonus rooms over garages, and the like are one of the largest and most common air leakage problems. This figure shows the air movement that allows outdoor air into all the joist bays, between floors. This problem can be eliminated by careful blocking of the floor framing under the knee wall, or by insulating the rafters and providing an air barrier, as shown in Figures 7.16-7.17.

FIGURE 7.16

1½-story knee wall outside the air barrier

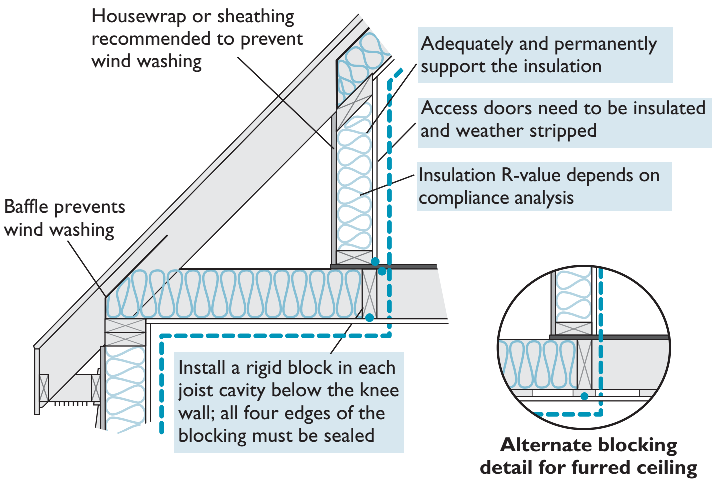


FIGURE 7.17

1½-story knee wall inside the air barrier

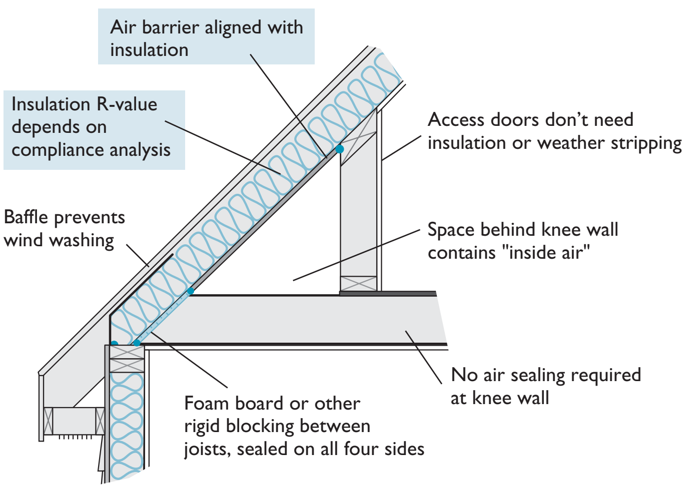
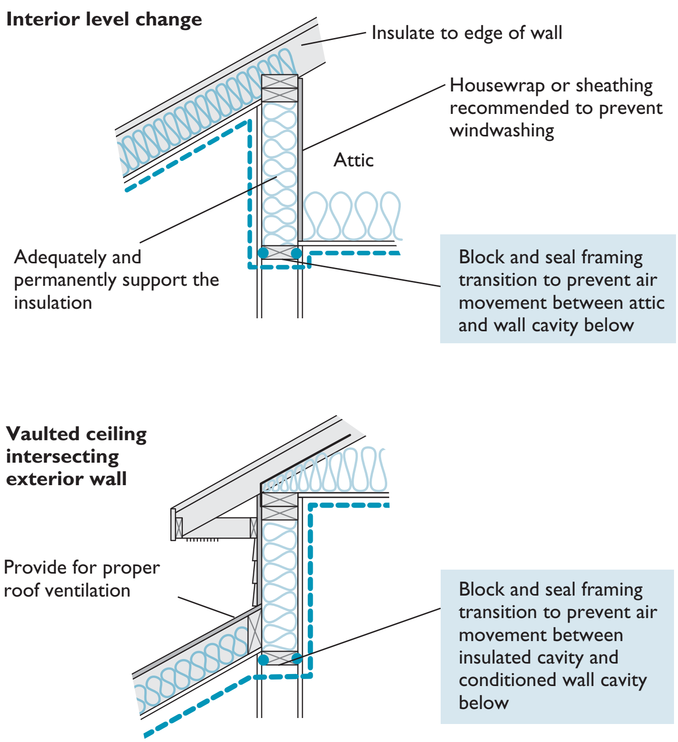


FIGURE 7.18
Sealing split levels



The lack of draftstop blocking in typical split-level details is another large leak. Be especially careful around stairways framed near these areas in “Tri-level” homes.

8

Windows and Doors

Energy Code Requirements

The primary window requirement in the energy code is for the *U-factor* of installed windows (which includes skylights and glass doors). Note that the U-factor is 1/R, which means smaller U-factors have better thermal performance. This U-factor requirement will vary depending on the results of your compliance analysis. There are only two ways that the code lets you determine the U-factors for a given window:

- **NFRC rating (IECC 102.5.2)—**In order to take credit for a manufacturer's rated "U-factor," the product must be listed by the National Fenestration Rating Council (NFRC). The rating is based on simulations that are verified by a laboratory test, and its purpose is to provide a "level playing field" for all manufacturers to compare their products. The rating information should be available in product catalogs, and there is a sticker attached to every unit. The sticker is shown in Figure 8.2, and displays the U-factor. Be sure you don't remove the stickers until your building inspector has verified the installed product's U-factors!
- **Default tables—**For products that do not have an NFRC rating, you can use IECC, Table 102.5.2. This table contains default U-factors for windows, glass doors, skylights and doors of various types. There are categories for single pane and double pane glass, and for various frame materials and sash types (Table 102.5.2[1]), as well as for different types of steel and wood doors, with and without storm doors (Table 102.5.2[2]). The main reason for the table is to provide U-factors for the occasional non-rated side lite, transom window, decorative glazing unit, or door. You can use the default values for every window in a house, as long as the house passes the compliance analysis. However, the default U-factors are conservative, and don't allow credit for low-e coatings, gas fills, or any other feature that can't be verified in the field.

- **Remember** that when you calculate window (or skylight or door) area for the purposes of code compliance, you must use the *whole* unit area (frame dimensions or rough opening). Don't use glass or sash sizes.

Prescriptive Compliance

If you use the prescriptive tables from IECC chapter 5, or the simplified prescriptive tables from IECC chapter 6, you will have a "Maximum" U-factor to use for all windows in the house. If you have windows (or skylights) with different U-factors, you can do an average U-factor calculation for the whole group. A worksheet for that purpose is included in this guide (see Appendix A).

Windows

Although people commonly refer to double glazing as "insulating glass," it's important to realize that windows are not "insulated." Windows typically represent three to ten times greater heat loss (per square foot) than wall assemblies. The "best" commonly available, mainstream windows (double, low-e, argon, without special heat mirror films or other premium features) have an R-value of just over 3—that's more than triple the heat loss of the worst wall that most people would ever build today (R-11).

Glazings have improved steadily over recent years. Fifty years ago, the vast majority of windows were single glazed. Double glazing, until recently the norm in virtually all cold climates in the country, is rapidly being supplanted by double low-e. The upgrade cost for low-e coatings continues to drop, and for many products low-e is already standard. A low-e coating is a thin, invisible metallic film that is added to one of the two inside surfaces of glass. This coating has the effect of reducing the radiative coupling between the two panes of glass, markedly improving thermal performance. Gas fills such as argon or krypton are also common. These gas fills are denser than the gas—air—that is used in standard double windows. The higher density of the gas reduces conductive looping inside the window, improving the thermal performance even more. These two features are usually complemented by "warm-edge" spacers. These edge spacers are made of plastic or foam (instead of metal, which was used in the past). Consequently, less heat is conducted through the frames of the windows. Extra layers of glass (or more commonly, plastic films such as "heat mirror") with additional low-e coatings are available as well—usually at a premium price, but they are increasingly affordable. The best (highest performance) windows currently available combine all of these features and have frames that are made of foam-filled rigid fiberglass. Foam-filled fiberglass frames conduct less heat than the typical wood or vinyl frames, and they are generally very durable and dimensionally stable.

The ENERGY STAR designation can be used as a baseline for window performance (see Figure 8.1). Note that the parameters vary by climate. While it is by no means a requirement to use ENERGY STAR windows in all ENERGY STAR Qualified New Homes, most builders do opt for them; the upgrade cost is fairly small for the benefits involved (efficiency, comfort, reduced condensation potential, etc.). To get a complete picture of the factors that affect the impact of window type on the energy performance of the building, you must also consider the following:

- **U-factors**—There are many different performance numbers associated with a given window type (see Figure 8.2). The only number that is used for energy code compliance is also one of the most important to you as a designer or builder; use the *whole-unit* U-factor (as determined by the National Fenestration Rating Council [NFRC]) to compare products. The lower the U-factor, the better it performs.
- **Solar Heat Gain Coeffiecient (SHGC)**—The SHGC is a measure of the amount of the sun's energy that is transmitted through a window. In Maryland's mixed-humid climate, the SHGC is also an important factor in assessing the impact of window selection on home performance (despite the fact that it is not used in determining energy code compliance). Again, the lower the number, the better it performs.
- **Orientation**—South facing glass reduces heating loads and adds little to cooling loads. South facing glass is good. If you have south facing glass area (not including frame area) that's more than 7% of the floor area of the building, you should think about adding extra thermal mass to avoid overheating. East and west facing glass does not reduce heating loads in winter, but is the primary source of summer cooling loads. Limit east and west glass if you can; if you need large areas of glazing in these directions, consider using "southern" low-e products (which often cost the same if you order in advance) with low SHGCs.
- **Shading** is another way to reduce unwanted heat gain from east and west facing glass. Trees, overhangs, decks, or awnings can all be used to reduce the time that the sun shines in these windows. On the south side, properly designed shading can admit the sun in winter when it is low in the sky and block it out in summer when the sun is high.

Window installation is another factor that can affect not only the energy efficiency of a house, but also its durability. Regardless of the window type selected, care should always be taken to ensure that any water that gets behind the siding or through the window frame is drained and shed down, out and over the sheathing wrap or building paper. Use a properly lapped sill flashing that is integrated with the building drainage plane. An excellent resource for this and related flashing details is the EEBA *Water Management Guide* (see Appendix B). Outdoor air should also be prevented from entering the house by sealing the window frame and/or casing to the rough opening in the framing (see Figures 8.3 and 8.4).

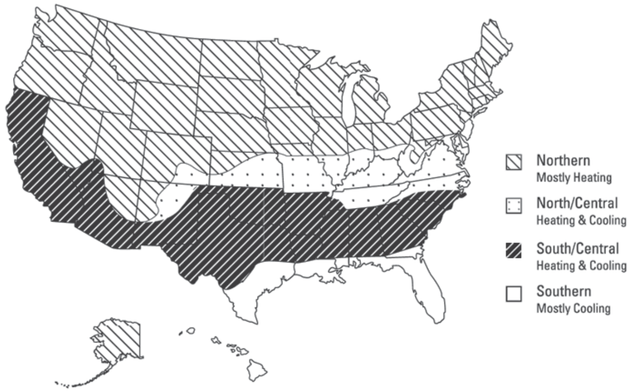
By carefully selecting windows, you can trade off upgrade costs immediately with dollars saved elsewhere. High performance glazings, when coupled with air sealing, can reduce peak heating and cooling loads, and allow substantial savings on mechanical equipment costs. For example, upgrading from double-pane to low-e glazings (or from low-e to heat mirror films), can reduce cooling loads by 1/2 to 1 ton in a typical house, saving enough on HVAC costs to pay for the window upgrade. Also, higher average surface temperatures and lack of drafts may allow HVAC contractors to put supply registers or baseboards near inside walls, saving significant installation costs.

Doors

Doors can generally be divided into two categories—those that are insulated and those that are not. Insulated doors typically have R-values between 2.5 and 7. Metal doors perform much better if they have *thermal breaks*—interruptions in the conductive metal components—built into the door and frame. Insulated fiberglass doors can achieve high R-values without special thermal breaks. Uninsulated doors (e.g. all wood doors) have R-values closer to 1. Most new doors that have any amount of glazing are also NFRC-rated (by U-factor), which makes it easier to compare one door to the next. Usually, aesthetics and price drive consumers to select one door over another, which is fine; doors take up a small enough area of the thermal envelope that the R-value has a small impact on the overall performance. Of course, all other things being equal, it's still a good idea to choose the most efficient one available.

FIGURE 8.1

ENERGY STAR qualification criteria by climate zone



	Windows and Doors		Skylights	
Zone	**U-factor**	**SHGC**	**U-factor**	**SHGC**
Northern	≤0.35	Any	≤0.60	Any
North/Central	≤0.40	≤0.55	≤0.60	≤0.40
South/Central	≤0.40	≤0.40	≤0.60	≤0.40
Southern	≤0.65	≤0.40	≤0.75	≤0.40

FIGURE 8.2

NFRC Sticker

NFRC
National Fenestration Rating Council
CERTIFIED

World's Best Window Co.

Millennium 2000+

Vinyl-Clad Wood Frame
Double Glazing • Argon Fill • Low E
Product Type: **Vertical Slider**

ENERGY PERFORMANCE RATINGS

U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
0.34	**0.25**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage (U.S./I-P)
0.41	**0.2**

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. Consult manufacturer's literature for other product performance information.
www.nfrc.org

The National Fenestration Rating Council (NFRC) rating is the only way allowed by code to verify the manufacturer's rated thermal performance of windows, skylights and glass doors. A sticker similar to the one shown above is attached to each window. In addition to the performance ratings expressed above, condensation resistance (measured on a scale from 0 to 100; the higher the number the better) may also appear on the label. The ratings associated with condensation resistance and air leakage (measured in CFM/square foot) are optional; the manufacturer decides whether or not to include them. Performance ratings can also be found in the NFRC Certified Products Directory (see Appendix B), or can be obtained directly from the manufacturer.

FIGURE 8.3
Window with wood trim

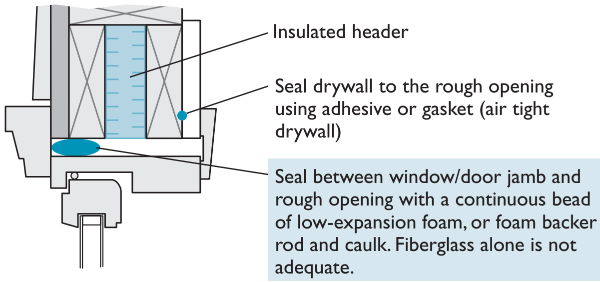
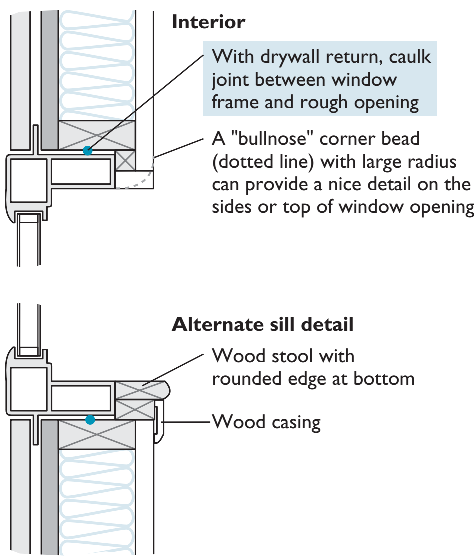


FIGURE 8.4
Window with drywall return



CAUTION: Do not use high-expansion foam. It may cause bowing of window and door frames and void the warranty.

9

Heating, Ventilation and Air-Conditioning (HVAC)

Energy Code Requirements

The energy requirements of the building code that apply to HVAC installations (IECC Section 503) are in addition to any plumbing, mechanical, and fuel gas codes that apply to these systems. Although it is generally the HVAC installer's responsibility to follow these requirements, the builder may also have to know what they are and to communicate them to the subs for a given project because they are in the building code. Here's a summary of the HVAC requirements. Remember that these requirements generally apply to all residential buildings, but more complex mechanical systems typically found in multifamily residences may have to meet additional requirements—see IECC Section 503 for more detail.

- **Heat loss calculations and system sizing (IECC 503.3.1 and Chapter 3)—**Heating and cooling load calculations must be done according to a specified process.

> Air Conditioning Contractors of America (ACCA) *Manual J* (see Appendix B for ordering information) is required by the IRC One and Two Family Dwelling Code (see Section M1401.3). The design parameters used for these calculations are given in IECC Chapters 3 and 9.

- **HVAC system efficiencies**—The minimum efficiency requirements for HVAC systems are given in IECC 503.2. Note that code minimums for efficiency follow federal minimum efficiency standards. See following table and the next bullet for more information.

Equipment	Rating	Minimum
Boilers (oil and gas)	Annual Fuel Utilization Efficiency	80
Furnaces (oil and gas)	Annual Fuel Utilization Efficiency	78
Heat Pumps (air source)	Heating Seasonal Performance Factor	6.8
Central Air Conditioning	Seasonal Energy Efficiency Ratio	10

- **Heating system trade-offs**—Many boilers and furnaces are more efficient than the code minimums. You can take credit in any of the compliance methods for systems with higher than minimum efficiency. Get the equipment efficiency ratings from your HVAC installer (or subcontractors you have worked with) *before* you do the compliance analysis. As a designer or builder you can specify high levels of efficiency, which makes it easier to meet the code. However, be careful to know in advance what your requirements are, and how much the upgrade costs.
- **HVAC controls (IECC 503.3.2 and 503.3.3.5)**—Temperature controls must include the capacity to be set to 55 degrees or lower (for heating) and/or 85 degrees or higher (for cooling). Thermostats used to control heating and cooling simultaneously must have a temperature range (of at least 5 degrees) within which calls for heating and cooling are either suspended or reduced. Similarly, humidistats must have the capacity to prevent energy consumption (suspend operation) between 30 and 60% relative humidity. Heat pumps that include auxiliary electric resistance heaters must have controls that lock out the auxiliary heaters above a preset outdoor temperature.

  All mechanical ventilation systems must have controls to shut down when ventilation is not required. When the system is shut down, automatic or gravity-driven dampers at the points of intake and exhaust must be closed.
- **Duct and pipe insulation** is required for all HVAC ductwork and pipes in unconditioned spaces, as indicated in IECC 503.3.3. There are *exceptions* for return ducts in basements and ducts or pipes inside HVAC equipment. For most single family work, the insulation must meet the levels shown in the following table. Note that flex duct must have R-value labels on the outside jacket (IECC 102.5.3).

Ducts in unconditioned space			Hydronic pipes in any unconditioned space		
Supply ducts	Return ducts in unconditioned attic or outside	Return ducts in all other unconditioned spaces	up to 2" pipe diameter	over 2" pipe diameter	runouts to individual terminals, up to 12' long
R-8	R-4	R-2	R-4 (1")	R-6 (1-1/2")	R-2 (1/2")

Table 9.1 Common Duct and Pipe Insulation Levels

- **Duct sealing** is required on all low-pressure ductwork (IECC 503.3.3.4). All portions of stud bays or joist cavities used as ductwork must also be sealed. All connections and seams (except longitudinal joints that lock) must be sealed with either mastic or fibrous tape embedded in mastic (see Figure 9.1). Only two types of tapes are permitted for use in duct sealing, and their applications are specific to the type of duct being installed. Respectively, tapes meeting UL 181A and 181B may only be used for rigid fiber ducts (A) and for flex ducts (B). **Duct tape is not allowed for duct sealing.**
- **Service Water Heating (IECC 504)**—If vertical pipe risers are used with conventional stand alone or indirect fired hot water tanks, heat traps (if not integral to the water heater) must be installed on both the inlet and outlet sides of the water heater. Tankless coils are prohibited unless calculations demonstrate an acceptable rate of standby loss.

  All pipes in recirculating hot water pipe loops must be insulated to limit heat loss. Generally, 1/2 inch of insulation is sufficient. For pipes in excess of 1" in diameter or for service temperatures in excess of 140°F, see IECC Table 504.5. Circulation pumps must be equipped with shutoffs.
- **Written materials** describing regular maintenance actions must be left with all HVAC and water heating equipment (IECC 102.3). A label with a reference to such material is also acceptable.

ENERGY STAR

Mechanical ventilation

There is little emphasis on indoor ventilation in building codes. Most builders meet requirements for “natural” ventilation by accident, with ordinary window and door openings. By contrast, many ENERGY STAR Qualified New Homes include a mechanical ventilation system. Controlled mechanical ventilation provides the following benefits:

- **Healthier indoor air**—ASHRAE recommends that residential buildings be maintained at 30 to 60% relative humidity for optimum health. Why? Some biological contaminants thrive in low or high humidity, but most are minimized in this range. How do you control the humidity? In any climate and in any season, the first step is to control the air exchange rate. In the winter, dryness is caused by excess air leakage; when dry outdoor air is heated, the relative humidity drops. High humidity on the other hand, is often caused by underventilation, and poor source exhaust for moisture-producing activities such as cooking and bathing. Control the dryness by limiting air leakage, and control the moisture by ventilating the house. In the summer, the only way to control humidity is with mechanical dehumidification or properly sized air conditioning systems (see pages 111-112).

  Leaving ventilation to random air leaks doesn't work. How do you know the building is leaky enough? Even leaky buildings tend to be underventilated in the spring and fall, when there's little driving force for air movement. They are also overventilated in the winter when the driving forces are large, and when it costs more money to heat up the leaking air. Leaving ventilation to operable windows and doors doesn't work; people don't like to open windows and doors in the winter when it's cold. Build the house tight enough to limit the air leakage, then give the occupants control over background ventilation rates.

- **Reduced moisture—**As well as healthier indoor air, controlled ventilation helps to limit moisture problems in the building. Every bathroom should have a fan that exhausts to outdoors. Be sure the fan actually works; use rigid or flexible metal ducts and keep runs as short as possible. Kitchen range hoods should be exhausted to outdoors, especially if there is a gas range. Don't use dryer hose, and keep metal or flexible aluminum duct runs as short as possible. Of course, ventilation may not be adequate if moisture is getting into the house because of improper foundation drainage, roofing, or siding details.
- **Improved comfort—**Sealing air leaks in the building limits overventilation and drafts. Ventilation contributes to improved comfort in several ways. Controlling background ventilation rates reduces cooking odors, damp musty smells, "stale air," and elevated levels of carbon dioxide. Ventilation also helps reduce concentrations of airborne contaminants from building materials and household activities. By controlling indoor humidity, air sealing and ventilation work together to improve comfort.
- **Fewer callbacks—**A newly built house has a lot of moisture in it. Foundations, frames, drywall, plaster and paint all bring water into a new home. Depending on the weather and other conditions,

there may be a lot of water, or even more water. The most likely time to get a moisture-related callback is in the first winter of occupancy. When a new homeowner calls you to say "Our windows are sweating and there's mildew in the bathroom," what will you tell them? "Open a window?" How about, "Set your ventilation system to run more often (or at a higher speed)." Presto, the moisture problem is gone. Healthier, more comfortable people are less likely to complain and more likely to provide referrals.

How much ventilation?

ENERGY STAR guidelines reference ASHRAE Standard 62.2 as a means of specifying mechanical ventilation. This standard calls for a minimum of 7.5 CFM of fresh air per occupant plus one CFM for every 100 square feet of living space. For most moderately tight homes, the ventilation rates shown below will supplement natural air leakage to a level sufficient to promote good indoor air quality.

Number of bedrooms	1	2	3	4	5
Ventilation CFM	30	45	60	75	90

Table 9.2 Background Ventilation Rates

To account for variances in occupant behavior and in home performance, the average flow rate should be adjustable with a variable speed control or a timer. It is also good practice to install a fan that has excess capacity (typically 40-70 CFM) to provide flexibility in meeting varying ventilation needs.

Types of ventilation systems

- **Bath fan system—**The easiest type of ventilation system to install is a simple exhaust fan system. Choose one bath fan to upgrade with a quiet fan (less than 1.5 sones, preferably). People won't use a fan that sounds like an airplane. Choose a model that is rated for continuous operation (typically 30,000 to 50,000 hours). This is to make sure it doesn't break after a year or two. The fan must be ducted to outdoors, with an insulated duct. Put a 24 hour timer on the electrical circuit, so the fan can run full time or part time, and so people can leave it off when they are not home. One type of timer is just like the one that plugs into the wall to turn lights on and off in the evening, except it is hard-wired in a single-gang box. You can also provide a switch or wind-up timer so that someone using the bathroom is able to turn the fan on regardless of the timer program. To use the kitchen range exhaust as the "boost" fan, be sure it is ducted to the outdoors. This type of system is inexpensive; makeup air comes in through small leaks that exist even in a very tight building. It is not as effective at getting fresh air to upstairs rooms as a fully ducted supply air system, such as an energy recovery system (see below).

- **Central exhaust—**This is a middle-of-the road type of system. You can run ducts from the bathrooms and kitchen to a central exhaust fan, which has a 24-hour timer or variable speed control. Be careful to size the ducts for adequate airflow, to balance the system properly, and to get adequate airflow from each bathroom for moisture removal. Most exhaust fans are not rated for range hood duty, so don't place the kitchen exhaust register right over the stove! This system also gets its makeup air through leaks in the building shell.
- **Return makeup air—**Return makeup air systems pull fresh air into the home through the return duct of a forced-air distribution system (see Figure 9.2). These systems are better than exhaust type systems at getting fresh air into all the rooms in a house. However, it is necessary to limit incoming airflow, and also to ensure adequate ventilation is provided when heating loads are small.
- **Energy recovery ventilation (ERV)** systems pull exhaust air from the bathrooms and kitchen, and deliver fresh air to the living area and bedrooms, or to the return plenum of a whole-house air handler (see Figure 9.3). The two air streams run through an exchange core where heat and humidity are transferred from one stream to the other. Be aware that even a large ERV may not adequately remove moisture from bathrooms if the exhaust ducts are run to many locations; it may be better to use a smaller ERV unit and to install separate bath fans for fast removal of steam. **Heat recovery ventilators** (HRVs) do not transfer moisture between the two air streams and are more appropriate in homes without air conditioning.

Other HVAC recommendations

- **Bring ducts and pipes inside—**Ducts and pipes in unconditioned attics, garages, basements and crawlspaces lead to higher heat loss, discomfort, and ice dams. *Whenever* possible, bring the mechanicals inside the insulated envelope of the house. Builders and designers can help make sure that framers leave room to run the heating and cooling distribution system inside the thermal envelope.
- **Avoid ducts in outside walls—**If you must put a heating duct in an outside wall cavity, install *at least* R-14 rigid insulation between the duct and the exterior sheathing.
- **Use high efficiency equipment,** which will save the buyer money, and is one of the easiest ways to get credit toward ENERGY STAR or the energy code. Many utility companies have rebates or incentives available to help offset the higher purchase price of high efficiency heating or cooling systems. These incentives are usually linked to the following ENERGY STAR performance standards:

Equipment	Rating	Minimum
Boilers (oil and gas)	Annual Fuel Utilization Efficiency	85
Furnaces (oil and gas)	Annual Fuel Utilization Efficiency	90
Heat Pumps (air source)	Heating Seasonal Performance Factor	8.0
Central Air Conditioning	Seasonal Energy Efficiency Ratio	13

Note that these performance standards are for HVAC systems only, and that the specification of these systems is only a recommendation, not a requirement of participating in the ENERGY STAR for New Homes program.

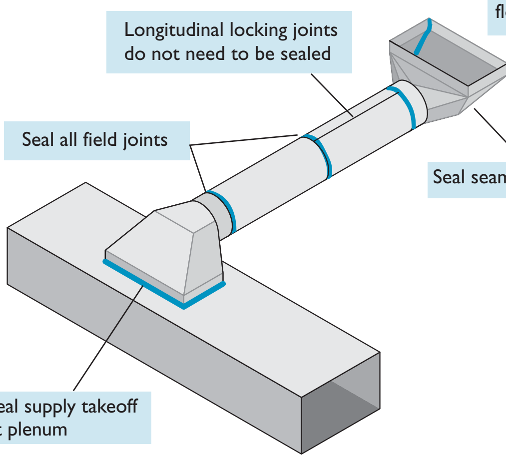
- **Use sealed combustion** to avoid backdrafting and carbon monoxide in the home. Figure 9.4 shows one typical backdrafting scenario; any large exhaust fan can backdraft atmospheric vented combustion appliances. Installation of sealed combustion boilers, furnaces, and water heaters may avoid the expense of building a chimney; many of them can vent through the side wall (see Figure 9.5).
- **Use integrated systems—**Integrated heating/hot water systems can save energy and also save on installation costs. If you have a boiler, using an indirect fired water storage tank is much more efficient than a standalone tank, uses only one burner to do both jobs, and needs only one venting system. If forced air is desired, a boiler can provide heat through a "hydro-air" fan coil. In a house with small heating loads, the fan coil can be supplied by a small, high efficiency, stainless steel water heater with a heat exchanger. This approach also saves space. Avoid tankless coils for water heating; they have the lowest efficiency of all.
- **Proper sizing** of heating systems may save only a little money on the boiler or furnace itself. Proper sizing of the distribution and/or cooling system, however, can save hundreds of dollars in a typical house. Heating and cooling loads should be calculated on a room-by-room basis (using ACCA *Manual J* or other approved method, see page 69). Ducts, air handlers, hydronic baseboard and circulating pumps should also be sized to actual loads, rather than rules of thumb. Efficient homes with low-e glazings and no drafts need less heating and cooling and smaller distribution systems than rules of thumb typically indicate. Occupants may be comfortable with registers or baseboards located closer to the center of the building, rather than the standard practice of delivering heating and cooling near exterior walls. Properly sized air conditioning may be healthier for the occupants as well (see page 112).

Going Further

There are a number of references listed in Appendix B specifically related to indoor air quality, ventilation, and HVAC systems.

FIGURE 9.1
Sealing duct runs within unconditioned spaces

Use mastic to seal all the locations shown here. Use fiberglass mesh as reinforcement for gaps larger than 1/8".



Leaky ductwork in unconditioned basements and attics is a major source of heating and cooling losses. Run ducts inside the conditioned envelope wherever possible; duct sealing is not required in conditioned spaces.

To apply mastic, use vinyl gloves and smear it in place by hand. Pay close attention to:

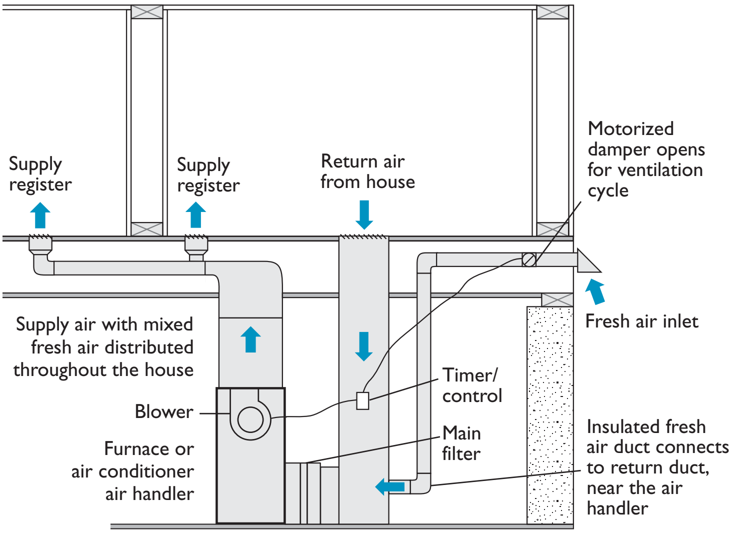
- folded corners on end caps, boots and takeoffs;
- plenum connections;
- filter racks;
- swivel elbows; and
- finger-jointed collars

TIPS: Mastic is much faster to install and more reliable than the more common aluminum tapes, and is the only sealant that is pre-approved in the energy code.

Air distribution can be improved by sealing the *entire* duct distribution system (and not just the portions of the system that are in unconditioned spaces).

FIGURE 9.2

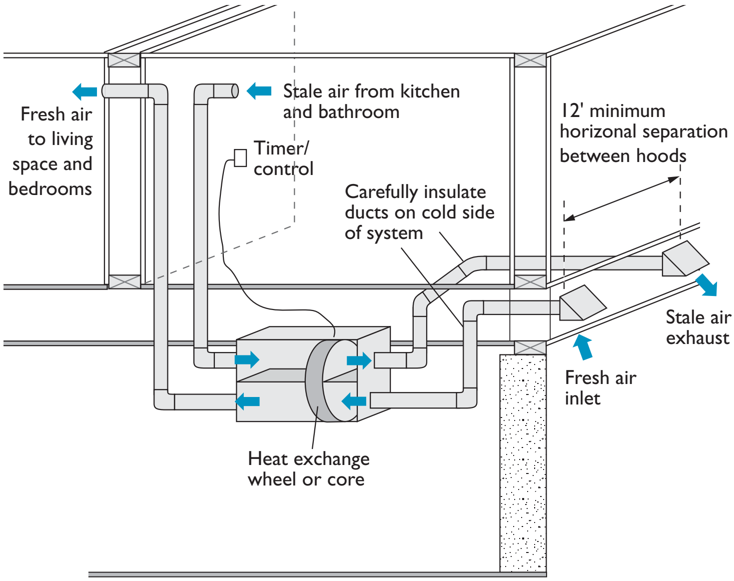
Return duct fresh air



TIP: Although the Return Duct fresh air system can filter and distribute fresh air throughout the house, the air handler blower may consume substantially more electricity. Low-energy, variable speed blower motors are recommended.

FIGURE 9.3

Energy (or heat) recovery ventilation

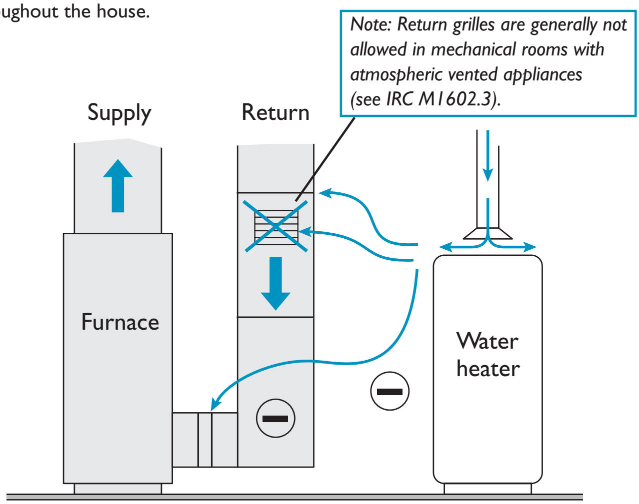


TIP: As an alternate, fresh air may be ducted to the return side of a central air handler for distribution throughout the house.

FIGURE 9.4

Depressurization and backdrafting

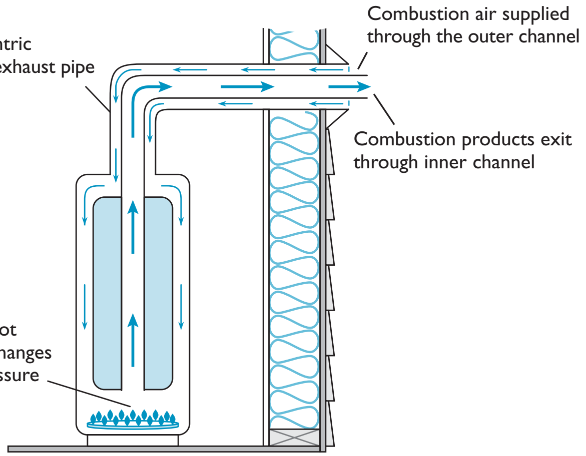
This figure shows a typical scenario. Leaks in return ducts depressurize the basement. Depressurization can backdraft the water heater vent or the furnace burner. Backdrafted combustion products, which may include deadly carbon monoxide, are then circulated throughout the house.



Depressurization that causes backdrafting can be created by any exhaust appliance. The large ones that are most likely to create depressurization include range vents, whole house fans, dryers, central vacuum, and fireplaces without outdoor air supply. Leaks in return ducts and/or the presence of return air registers in the vicinity of a combustion appliance can also cause backdrafting (as shown in the diagram above). **Mechanical code requirements for passive combustion air inlets or volume of air space do not guarantee against backdrafting**, yet they add to building heat loss.

FIGURE 9.5

Direct vent water heater



TIP: The placement of a direct vent appliance is limited by the allowable length of the intake/exhaust pipe. Plan carefully for locating these appliances.

The direct vent water heater is completely sealed from indoor air, so backdrafting into the living space cannot occur. Similar arrangements are available for furnaces, boilers, and gas or wood fireplaces and stoves.

FIGURE 9.6
Duct problems to avoid

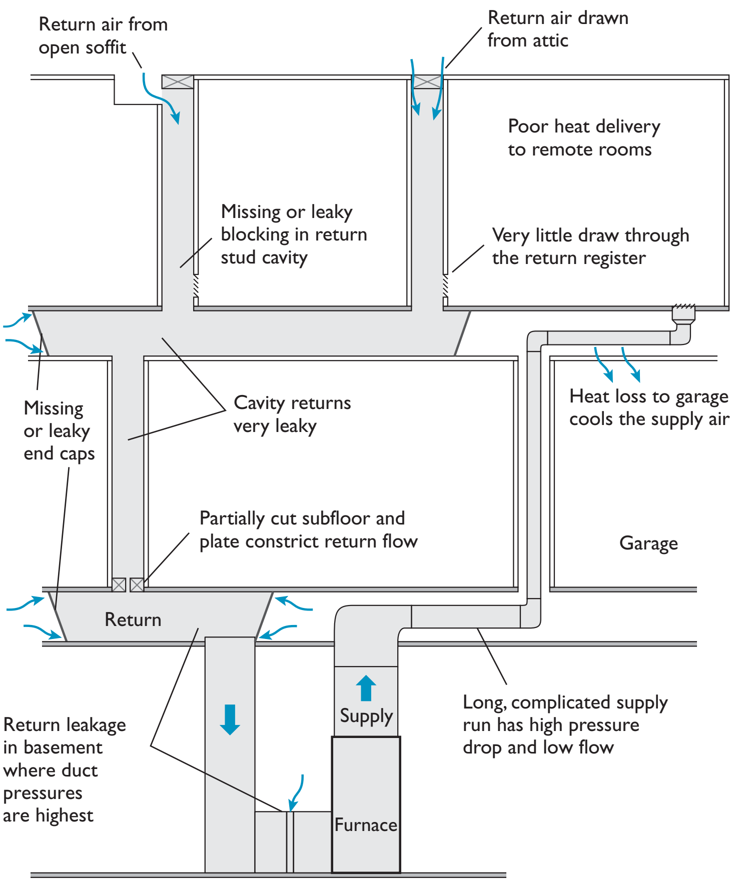
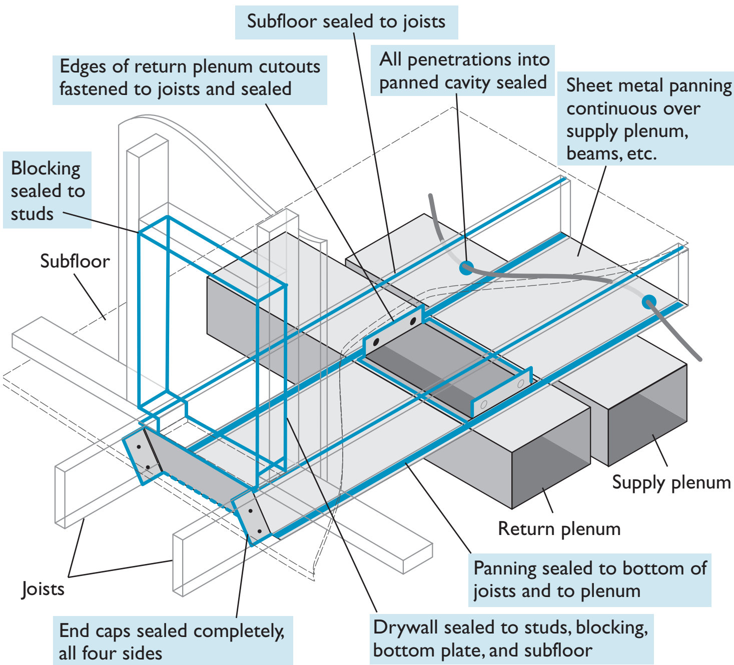


FIGURE 9.7
Building cavity returns



Sealing joist and wall cavity ducts is required by code, but is so complex that it is difficult to do well. The Air Conditioning Contractors of America (ACCA) discourages the use of building cavities as air ducts. Use fully ducted systems wherever possible.

TIP: It is better to have two or three central returns that are fully ducted and well sealed, than to have a leaky return in every room. Provide for pressure relief from rooms without returns by installing undercut doors or transfer grilles.

10

Plumbing and Electrical

Energy Code Requirements

Sealing penetrations

All penetrations through the insulated envelope of the building must be sealed (see Chapter 11). This can be done by individual subcontractors, but is more likely to be done by the builder. Electricians and plumbers can help by cutting holes slightly oversized to allow room for spray foam (see Figure 11.4), and by minimizing unnecessary penetrations.

Recessed lights

Recessed lights in insulated ceilings must be rated for Insulation Contact ("IC" rated), and must be airtight as outlined in IECC 502.1.3. Don't forget to include gaskets on the trim ring or other components that may be specified for the system to be rated for airtightness. The airtightness standard of 2.0 CFM, (ASTM E 283) is the same that was adopted by Washington state. Units with a label that references this ASTM standard, MEC, IECC, or Washington State's energy code will be accepted. This requirement can also be satisfied by installing sealed, airtight boxes over recessed lights.

Tub/shower units on exterior walls

Be sure these have an adequate air barrier in place before installing the unit. This includes insulation and vapor retarder as well. See Figure 11.8.

ENERGY STAR

Plumbing and electrical penetrations are major sources of air leakage in buildings. In addition, pipes and wires in exterior walls can make it difficult to install insulation properly. Keep plumbing out of exterior walls whenever possible (especially if the walls are being insulated with fiberglass batts). Try to run electrical wires low across walls, so it is easier to split batts on either side. If the walls are insulated with a blown- or sprayed-in insulation, there is less concern about interference. It's still a good idea to run plumbing in interior walls, or stay as close as possible to the interior in a 2x6 or larger wall, to avoid problems with freezing pipes.

11

Air Sealing

Energy Code Requirements

The code has a list of areas that must be sealed (IECC 502.1.4.2), and gives examples of sealants to use. The leaks to be sealed include leaks between conditioned and unconditioned space, and leaks between conditioned space and outdoors. Note that fiberglass batts do not stop air and cannot be used as a sealant.

It is interesting to note the extent to which code requirements for air sealing and fireblocking overlap: "Fireblocking shall be provided to cut off all concealed draft openings (both vertical and horizontal) …" (IRC Section R602.8). Fire is much the same physically as heat loss, except it's much faster and more destructive. Specific fireblocking requirements parallel the requirements for air sealing that are outlined in the IECC, calling for draft stops that address the following:

- Hidden leaks in walls that intersect with attics and/or basements, including the openings around and associated with chimneys, ducts, vents, furred ceiling spaces, and the like (chaseways and cavities).
- Leaks that result from a change in ceiling height (e.g. soffits, drop ceilings).
- Leakage pathways associated with stair stringers.

In general, wherever draftstopping makes sense from an energy perspective, it is probably also required by fire code. Fire code however, may call for draft stops in places that do not align with the thermal envelope (such as between two heated floors). With respect to energy efficiency, these stops are less of a concern.

Fireblocking and air sealing requirements not only overlap, but are also complimentary. With fireblocking, the emphasis is placed on selecting an appropriate material to serve as a draft stop (acceptable materials include 2" of lumber, 3/4" nominal plywood or particle board, 1/2" drywall or 1/4" cement board). Energy code complements this requirement by calling for the perimeters of these stops (or baffles) to be sealed to the surrounding surfaces. Both steps are required to achieve a complete and effective air barrier.

It is important to note that there is also one way in which these two sections of the code are *not* complementary. In addition to the items listed above, mineral and glass fiber materials are also allowed for use as fire stops. Fibrous materials however, are ineffective at stopping air. Consequently, they should not be used where air sealing is required.

The IECC goes on to require sealed draft stops anywhere there are openings between conditioned and unconditioned space. The following is a list of some of the most important locations:

- **Between wall and roof or ceiling; wall and floor; between wall panels.** These are often some of the largest leaks in a house. They typically occur in places where cavities between studs or joists connect a conditioned space to an attic or basement area. “Draftstop” blocking is the simplest way to deal with these leaks. Typical examples are shown in Figures 7.11-7.18.
- **Penetrations** of utility services through walls, floors, ceiling/roofs, wall plates. Plumbing, electrical, duct and chimney chases are examples of these leaks. See Figures 6.5, 7.8, 7.11-7.12, 7.14, and 11.1-11.7.
- **Door and window frames—**Rough openings should be sealed to frames with low expansion foam, caulking, or backer rod and caulk. Be careful, even with low expansion foam; if you fill large spaces it can still push out the jambs. To control this, don’t worry about filling the entire space; just bridge the gap between the rough opening and the jamb. See Figures 8.3 and 8.4.
- **At foundation/sill—**The numerous framing members between the top of a foundation wall and the toe plate of the wall above allow significant leakage. The weight of a house is not enough to force these pieces together. Foam “sill seal” between the foundation and sill is commonly used. In addition, seal the band joist area according to Figure 7.1 or 7.2. Note: vertical “steps” in the foundation height (where the grade changes) need special attention to avoid air leakage. Sill sealer will not generally stop air leakage in these locations.
- **Around/behind tubs and showers—**These leaks cause heat loss, and are common causes of comfort complaints and freezing pipes. Bathrooms

over garages are especially prone to such problems. See Figures 11.7-11.8.

- **At attic and crawlspace panels—**Attic scuttles, pull-down stairs, access doors through knee walls into unheated attic spaces, and access from a conditioned basement space into a crawlspace all need weather-stripping as well as insulation. See Figure 11.10.
- **At recessed lights—**The requirements for recessed lights are given on page 83, and Figure 11.9.

Durable caulking, gaskets, tapes and/or housewraps should be used to seal these areas. The code also says to "allow for differential expansion and contraction of the construction materials," for example where wood, metal, concrete and/or plastic join each other. If you use housewrap for an air barrier, it should be installed according to manufacturer's instructions. These instructions generally call for careful detailing and taping of all seams, including—but not limited to—the edges around window and door openings, at the sill area, and where exterior walls meet roof lines. Also note that housewrap generally does not address many of the most significant leakage pathways in a house (which are typically found in attics and basements). See page 112 for more information about bulk water control.

ENERGY STAR

Air sealing is an important part of energy efficient construction, but does not neatly fit into any one category of subcontractor. Some air sealing is done most easily by framers as they put the pieces together. Some can be done by drywall crews. Some insulation contractors specialize in air sealing. But it is the builder who is ultimately responsible to see that adequate air sealing is done by the right people at the right times. If planned thoughtfully and done at the right stages of construction, most air sealing can be done with very little added expense. If you pay attention to the air sealing requirements of the energy code, you will already be well on the way to building an ENERGY STAR Qualified New Home.

The concept of air sealing is to provide a continuous air barrier all the way around the house. It does not mean hermetically sealing the building—there will always be leaks and cracks where air can get in and out. It does mean thinking about what material is going to stop indoor air from mixing with outdoor air. See Figure 11.1 for an example of this concept. Note that in all drawings, the dotted line (in color) represents the primary air barrier.

Here are some hints to help with air sealing:

- **Get the biggest leaks first.** This may seem obvious but it's not.

There's little point in caulking the small cracks or sealing electrical boxes if you have a plumbing chase or floor system that leaves a hole of ten, or twenty, or forty square feet, straight into an attic. A simple rule of thumb is, first seal up the ones you can crawl through. Then seal up the ones a cat can crawl through. Then go after the details.

- **Get the least expensive ones next.** Think about ways that you can build air sealing into tasks you are doing anyway, with materials that are on hand. Some examples: specify drywall adhesive or acoustical sealant on top plates and end studs of partition walls. Specify construction adhesive on all layers of floor framing instead of just the subfloor. Use leftover scraps of rigid insulation to block off chases or floor cavities. Then, before drywall is hung, have one person go around with a foam gun and seal up all the small wiring and plumbing penetrations in top plates or end studs, as well as the window and door frames. If you do whatever you can in two or three hours, it will make a big difference in most houses.
- **Once the drywall is up, all the leaks become invisible.** They don't go away—they just disappear so you can't see them. Walk through the house before the drywall crew shows up, imagine that only the ceiling sheetrock has been applied and ask yourself, "Can I stick my hand past the sheetrock, through the insulation and into an attic space from here?" Then imagine the sheetrock has been applied only to the walls and ask yourself a similar question: "Can I stick my hand through the insulation to the outside or to an unconditioned space (e.g., a garage) from here?" If the answer to either question is "Yes," then draft stops or blocking should be added before the drywall is hung. It will never happen later. (Of course if you are using "air tight drywall approach" then the drywall itself may be a substantial component of your air barrier. See Figures 11.1-11.3 for more information.)
- **Insulation does not necessarily make a house air tight.** There are some cases however, when it can help. Spray foam, for example, has inherent air sealing characteristics. The use of other insulation systems, such as Structural Insulated Panels (SIPs), Insulated Concrete Forms (ICFs), or (to a lesser extent) damp-spray or dense pack cellulose, can also contribute to a reduction in air leakage. Regardless of the insulation type or system being used, it is essential not to rely entirely on insulation to do the job of air sealing. None of these systems will adequately seal large chases. Care should always be taken to identify and address remaining leakage pathways.

Other techniques

Much of the focus on building very tight buildings has historically concentrated on interior air barriers, particularly sealing and detailing of polyethylene vapor retarders as the primary air barrier. This should not be done in any house that has air conditioning. Use a material that's already there, such as the drywall or exterior sheathing, as the primary air barrier. The use of "airtight drywall," for example, can significantly enhance the air tightness of a home at little extra cost (see page 107).

What if I build the house too tight?
There is no way to build a house "too tight." Tight is good. You *can* build an underventilated house (see pages 71-74), but not if you put in a ventilation system. Tight houses save the customer money and reduce callbacks, *but you must* install ventilation. Mechanical ventilation is strongly recommended for all new homes because it's the only way to ensure background air change rates, regardless of how tight the house is. And the ventilation air will cost *less to heat than a leaky house*, every time.

Going Further

In addition to energy savings, you get other important advantages by building a tighter house. Tight construction can help reduce:

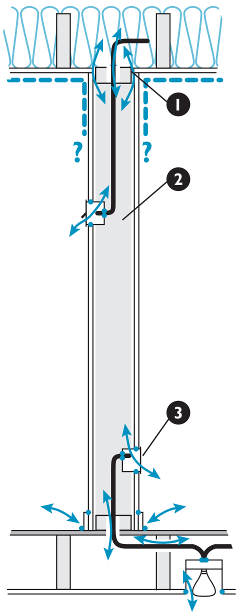
- **Ice dams—**Most discussion of ice dam prevention concentrates on passive ventilation of the roof sheathing, such as continuous soffit and ridge vents. Ice dams are caused by heat in the attic melting snow from the bottom. Although ventilation does dilute heat that gets into the attic, reducing the *flow* of heat is more important. Sealing up air leaks into the attic is the most important factor in reducing ice dams, followed by keeping HVAC out of the attic, and proper insulation.
- **Moisture in building frame—**Most of the focus on preventing water vapor from getting to cold surfaces (wall sheathing, attic structures, etc.) has traditionally centered on vapor retarders. Vapor retarders are important; but it has been shown that over 100 times more water vapor is carried into these spaces by leaking warm, moist air, than by diffusion. Seal up the air leaks (and install mechanical ventilation) to reduce moisture that causes structural damage and health risks. See the EEBA *Builder's Guide* for more on the relationship between vapor diffusion retarders and air flow retarders, and the mechanisms of vapor diffusion.
- **Freezing pipe problems—**Most pipe freeze-ups are a result of moving cold air, not just cold temperatures. Of course it is important to keep pipes on the warm side of insulated assemblies. However, it is also critical to define a good air barrier and keep the pipes on the "inside." Many pipe freezes occur in areas such as garage ceilings, kneewall floors, and other places where the air barrier is typically not well defined. See Figures 7.12 and 7.15.

- **Insects and rodents—**Of course air sealing alone won't keep vermin outside the building, but it will greatly reduce their access to the living space. Be careful about exterior rigid insulation on foundations, which can provide invisible insect access into the house (see page 32).

FIGURE 11.1

Strategic sealing: interior partition wall intersection with attic

Poorly defined air barrier | **Well defined air barrier**



A lot of material and effort may be needed with no guarantee that leakage will be stopped.

1. Air barrier is broken at attic/wall intersection. Top plate shrinks away from drywall when wood dries
2. Wall cavity serves as duct linking unconditioned attic to rest of house
3. Many potential air leakage paths. Sealing one may simply shift leakage to another.

Sealing the top plate, before the drywall is hung, requires little effort and completes the air barrier at the insulated ceiling.

1. Seal top plate penetrations
2. Seal drywall to framing–"airtight drywall approach"
3. "Inside air"
4. No need to seal drywall penetrations in interior wall

FIGURE 11.2
Sealing intersections at the ceiling

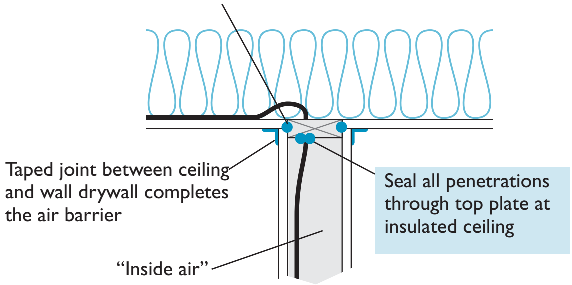
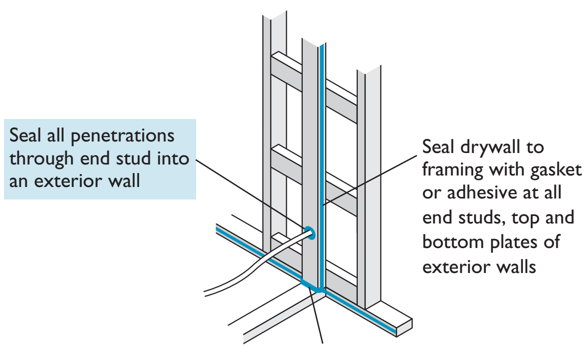
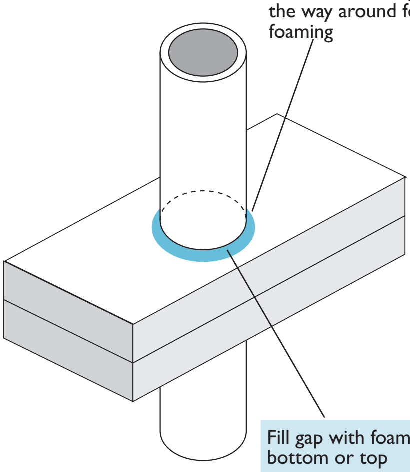


FIGURE 11.3
Sealing intersections at exterior walls



The sealing techniques shown in Figures 11.1 to 11.3 are the fundamental components of "airtight drywall approach" (which includes airtight or sealed electrical boxes, and carefully sealed band joists as well). Even if you are not using a complete "airtight drywall" system, specifying adhesives at top plates and end studs will significantly reduce air leakage. Be especially careful at the intersections where multiple partition walls meet each other at insulated ceilings.

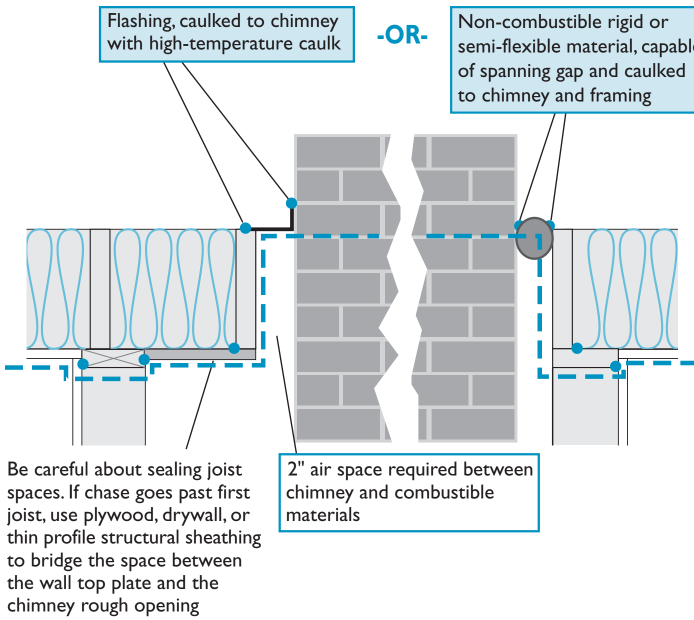
FIGURE 11.4
Sealing plumbing vent pipes



Plumbing vent pipes can be sealed with foam from above or below. Long, straight pipe runs may be sealed using a rubber boot or roof boot to address the movement of pipes relative to the framing. This requires coordination with the plumber, to install it as the pipe goes in.

FIGURE 11.5

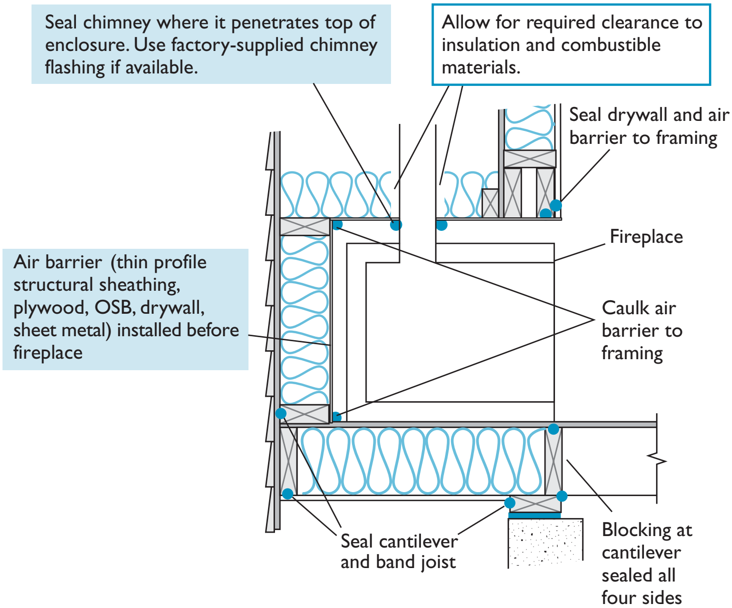
Chimney Chases



NOTE: Duct chases can be just as large a leak, but ducts can be sealed directly to framing with spray foam.

Unsealed chimney chases are often one of the largest leaks in a house. Be careful to keep combustible materials at least 2" from the chimney, and use high-temperature silicone caulking or firestop caulk. Many prefabricated chimneys have draft blocking and/or insulation guard kits available to fit them; follow the manufacturer's instructions.

FIGURE 11.6
Air sealing fireplace enclosures



TIP: In some instances with complex framing, such as a home entertainment center recessed above the fireplace cavity, it may be simpler to use the exterior sheathing as the air barrier. However, it is still necessary to seal the top of the chase as shown in Figure 11.5.

Be sure to install the air barriers and do the sealing before the fireplace is set in place.

FIGURE 11.7

Boxed-in tub in insulated floor

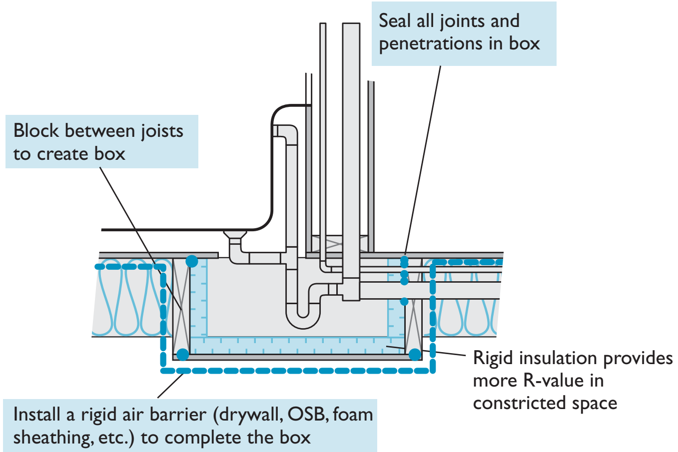
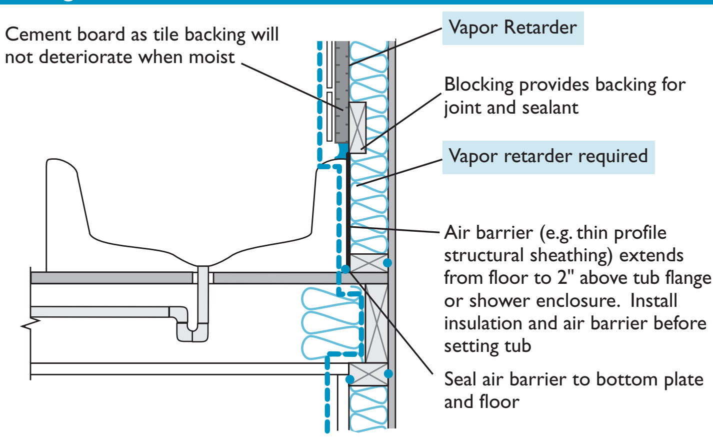


FIGURE 11.8

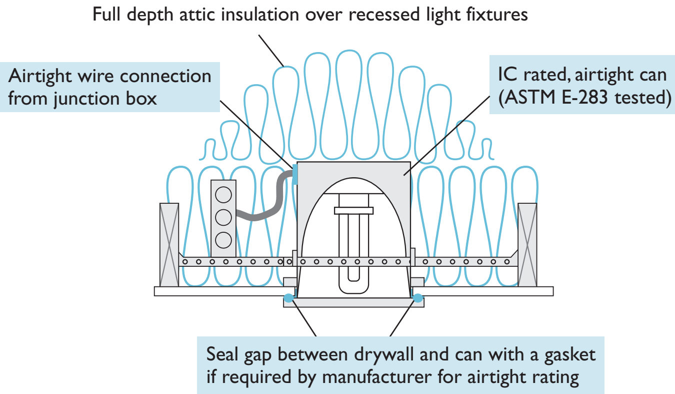
Sealing tub and shower enclosures



CAUTION: Do not use standard or moisture resistant drywall as a tile backing material in this application. They deteriorate when they get wet.

FIGURE 11.9

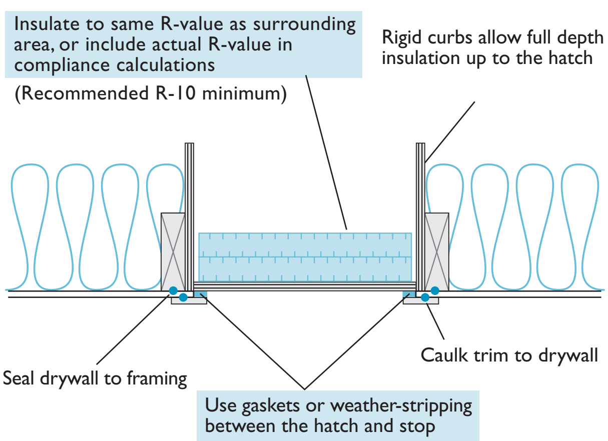
Recessed lights



CAUTION: Recessed lights must be specifically designed for air tightness and for insulation contact. Do not attempt to seal or insulate recessed lights that are not designed for this purpose.

FIGURE 11.10

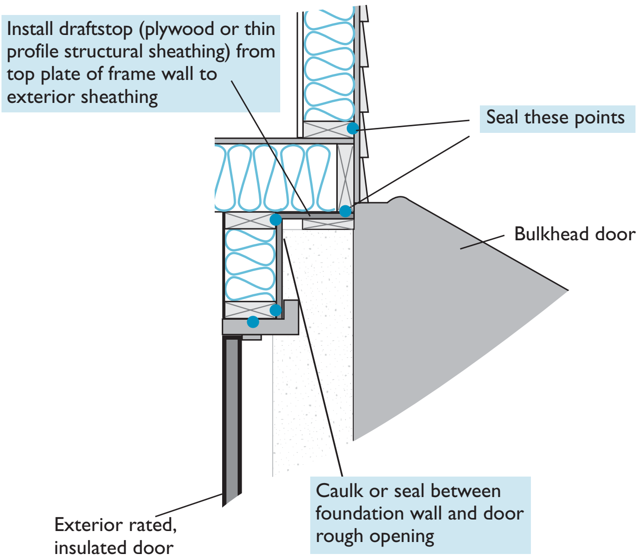
Attic hatch



TIP: If the attic is accessed from an unheated space, like a garage, hatch air sealing and insulation are not required.

FIGURE 11.11

Bulkhead door detail



CAUTION: This area may contribute to air leakage even in an uninsulated basement.

12

Insulation

Energy Code Requirements

Insulation R-values

The R-values of insulation in any part of the thermal envelope are defined by your compliance analysis. Whether it is a prescriptive table, a RES*check* printout or any other approach, the minimum R-value for each component is specified and documented with the building permit application (IECC Section 104). If, during construction, you want to substitute a lower than specified R-value for a particular component (wall, ceiling, etc.), you must redo to the compliance analysis to see if that will pass the code, and re-submit the paperwork with the new specifications. You may have to substitute higher R-values somewhere else in the building to compensate, or choose a different prescriptive package.

Proper installation

All R-values are based on proper installation. For fiberglass batts, this means:

- **Full loft—**Insulation should be fluffed to its full thickness, not compressed, and not rounded or scalloped at the edges.
- **Fill the cavity—**Insulation should be in snug contact with all wall studs, plates, sheathing and drywall. In ceilings and floors, it should be in contact with the drywall or subfloor, and extend all the way to joists on both sides without gaps (see Figure 12.2).
- **Cut around obstacles—**Insulation should be split around wires and small pipes; cut out around electrical boxes, larger pipes and other obstacles; and split over cross bridging in floors. Never stuff insulation in to get it to fit (see Figure 12.1).

Refer to industry standards such as *Fiber Glass Building Insulation: Recommendations for Installation in Residential and other Light-Frame Construction* (North American Insulation Manufacturers Association), or *Standard Practice for Installing Cellulose Building Insulation* and *Standard Practice for the Installation of Sprayed Cellulosic Wall Cavity Insulation* (Cellulose Insulation Manufacturers Association). These resources are listed in Appendix B.

Documentation of R-values (IECC 102.4 and 102.5)
Many common insulation products have R-value markings right on them. Faced and unfaced fiberglass batts, and rigid foam insulation must be installed so the markings are visible to the building inspector. If you are using blown- or sprayed-in insulation such as cellulose, spray foam, or blown fiberglass, the installer should provide a certificate showing installed thickness, settled thickness, the square feet of coverage, the number of bags (or amount of material) used, and the net installed R-value. For blown-in attic insulation, "tell-tale" inch markers are also acceptable, provided they show installed thickness and settled thickness (one marker minimum per 300 square feet of attic.)

Credit for "raised truss" construction (IECC 602.1.2)
Insulation in flat or cathedral ceilings is assumed to be compressed over the exterior walls, as is typical (Figure 12.4). If you can install the insulation in such a way as to get the *full R-value* of insulation all the way to the outside of the exterior wall, then you can take credit for "raised truss" in the RES*check* software ceiling input box. In the prescriptive method a raised truss or its equivalent allows you to substitute R-30 insulation when R-38 is specified, or R-38 for R-49. For the other methods, it gives you some credit toward your point score. This does not mean you have to use a raised heel truss to get this credit; examples of alternative methods are shown in Figures 12.5-12.7, 12.9. Depending on the roof geometry and the care of installation, you may not even need to modify the framing. For example, a high-pitched roof truss with a large overhang may not need any special treatment to achieve the full R-value at the eaves.

Access Openings
Attic hatches, scuttles, pulldown stairs, etc. must be insulated to the same R-value as the surrounding area, or the actual R-value must be accounted for in your calculations (see Appendix A).

Steel Framing
Steel is an excellent conductor of heat. Consequently, the effective performance of insulation in steel framed building assemblies is reduced dramatically. Cold interior surfaces near the steel studs bring an increased potential for condensation and mold growth. Code accounts for the thermal "bridging" that results from the use of steel framing by making insulation requirements more stringent. The easiest way to meet these requirements is to add a layer of continuous,

rigid insulation that covers all the framing and acts as a thermal "break" (see IECC Tables 502.2.4.16 (1 and 2), 502.2.4.18 (1 and 2) and 502.2.4.19 for insulated steel and wood equivalencies).

Additions (IECC 502.2.5)
Energy code compliance for additions may be demonstrated in a number of different ways. Theoretically, they can be analyzed as part of a whole building analysis or independently from the rest of the house. You can also choose any of the available compliance pathways (systems analysis, component performance, etc.). Regardless of the approach, it may be difficult to achieve compliance based on the fact that additions typically have lots of window area. In response to this, a simplified prescriptive table specific to additions has been developed. In most cases, the use of this prescriptive table will be the simplest option (see page 8).

ENERGY STAR

Proper application of insulation materials is critical to the success of any ENERGY STAR Qualified New Home. Here are some guidelines in addition to the code requirements:

- **No side stapling—**Although side stapling of faced fiberglass batts is mentioned in industry standards, it is not recommended in ENERGY STAR Qualified New Homes because it compresses the installation (see Figure 12.3). Face stapling is often disliked by drywall installers. To lessen the potential impact, be sure to set staples firmly into the studs, avoid pulling fiberglass fibers over the face of the studs, and mark the stud locations on the floor.
- **High density fiberglass batts** such as R-13, R-15, and R-21 get a higher R-value in the same cavity. They also tend to be stiffer, and fluff up so it is easier to get a good fit without compression. Although not an ENERGY STAR requirement, it is a good idea to use high density batts if you are using fiberglass, and you can get credit for the added R-value in the code analysis as well.
- **Air barriers and eave baffles to prevent wind washing—**No matter how well you install insulation, cold air washing through it will not only severely compromise its effectiveness, but also increase condensation potential by cooling the vapor retarder. Eave baffles made of cardboard or foam board are essential (see Figures 12.5, 12.6 and 12.8); if the baffle extends above the top of the insulation, no vent chute or "propavent" is required. Also vulnerable are exposed insulated walls, such as attic knee walls (Figures 7.15, 7.16 and 7.18). Cover the exposed fiberglass on the attic side with a vapor permeable air barrier such as housewrap, polystyrene foam,

drywall, or similar material. Floor insulation over piers, cantilevers and the like should also be sealed to prevent outside air from circulating into the insulation (Figures 7.11 and 7.12). Flat or sloped attic insulation need not be covered, but baffles should be provided near eaves (see Figures 7.16, 7.17, and 12.5, 12.8, and 12.9).

- **Cavity fill types that improve air tightness—**Some insulation materials can help. See page 88.

- **Avoid strapped ceilings—**1x3 furring strips running perpendicular to the joists provide a cavity for free air circulation, which often compromises the insulation performance, especially near eaves and in cathedral ceilings. Once nailed in place, they also make it very difficult to install insulation properly. This is another area where money can be saved while thermal performance is improved.

- **Higher R-values in sloped ceilings** can be achieved with smaller framing by adding sister joists with plywood gussets (see Figure 12.9) or by adding a continuous layer of rigid insulation on the underside of the roof rafters.

FIGURE 12.1

Insulating around plumbing, wiring, and other obstacles

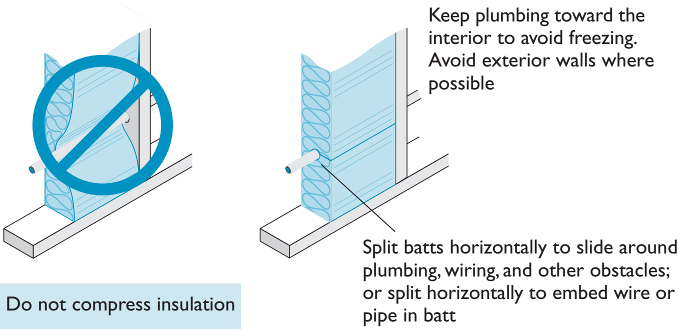
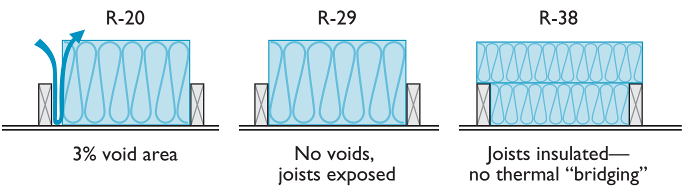


FIGURE 12.2

Effective R-value of insulation

This schematic shows the effect of insulation installation quality and technique on effective (or installed) R-values. Note that the same depth of insulation (12", nominally R-38) is used in all three cases.



CAUTION: Most of initial R-value is lost as void area increases. Increasing the void area above from 3% to just 6% for example, would result in an effective R-value of only 15.

FIGURE 12.3

Face-stapling versus inset stapling kraft-faced batts

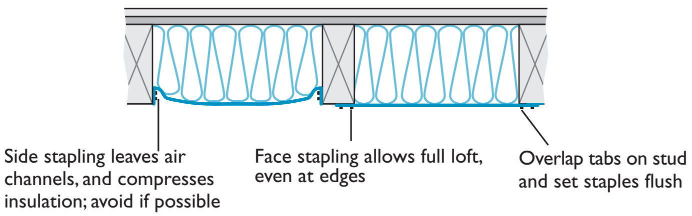


FIGURE 12.4
Conventional truss

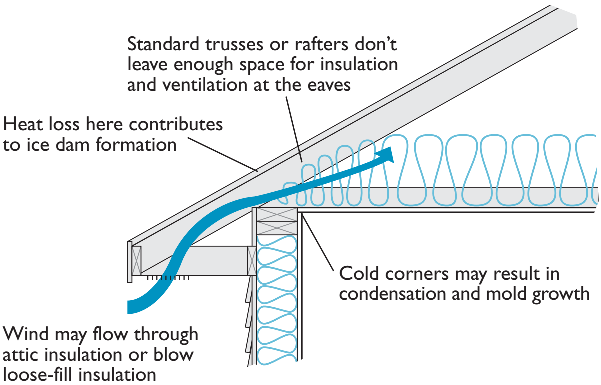
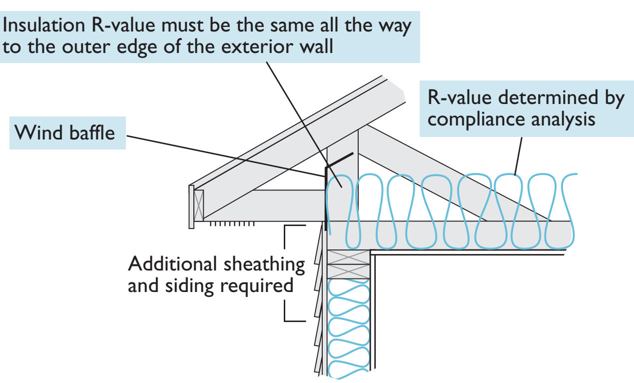


FIGURE 12.5
Raised heel truss

Raised heel trusses can be ordered for any eave height.



Credit is given in the compliance analysis for better performance. See Figures 12.6 and 12.7 for other options.

CAUTION: Trusses must be sized carefully so that the truss heel lines up with the edge of the wall below.

FIGURE 12.6

Conventional truss or rafter with insulated eaves

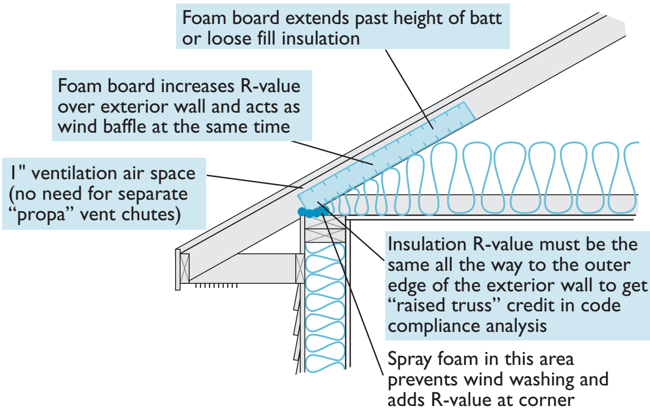


FIGURE 12.7

Conventional rafter with raised plate

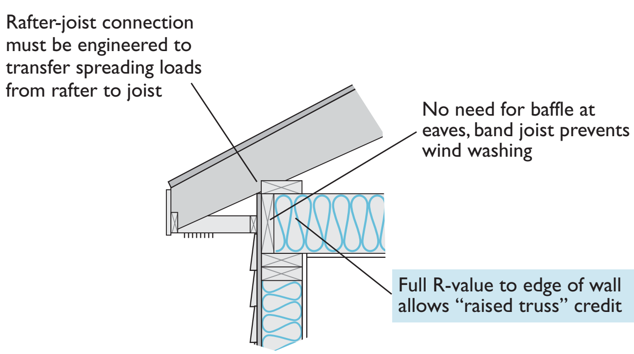


FIGURE 12.8

Vented cathedral ceiling

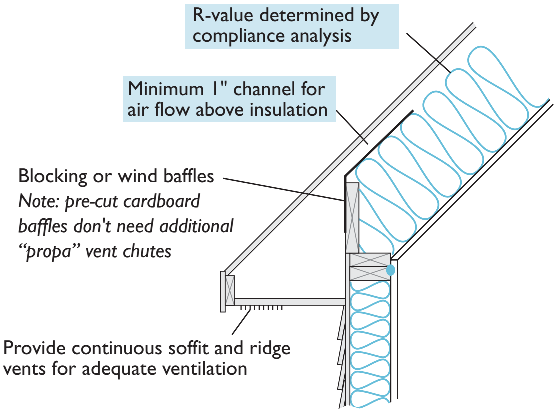
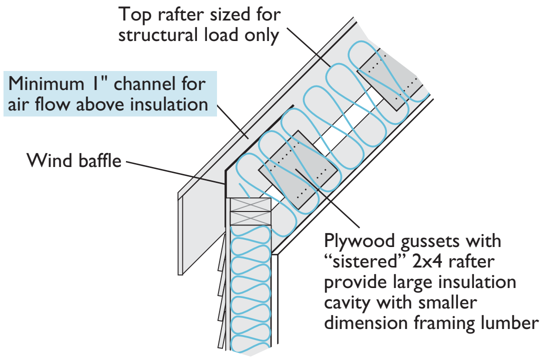


FIGURE 12.9

Cathedral ceiling with built-up rafters



13

Drywall

Energy Code Requirements

There are no specific requirements in the energy code that impact drywall or its installation.

ENERGY STAR

The application and use of gypsum drywall in itself does not have a large impact on energy use, or on ENERGY STAR certification (except where airtight drywall techniques are used). However, there are a number of things to be aware of concerning drywall:

- **Double check air sealing details** before you install the drywall. Once the boards are up, you can't see that areas need draftstopping or sealants. Look for the big holes! (See pages 87-88).
- **Nailing** should be kept to a minimum in corners. Let one side of inside corners float to help prevent cracks and nail "pops" (do provide backing so the drywall doesn't get pushed out during taping). See the EEBA *Builder's Guide* for more on drywall nailing techniques.
- **"Airtight drywall approach"**—If you use adhesive or acoustical sealant to attach drywall to top plates and end studs of partition walls, where they meet insulated walls and ceilings, this helps keep the air in the wall from getting "out." Add adhesive around window and door rough openings, caulk around electrical boxes, to complete a reasonable air barrier. At a minimum, specify adhesive on all top plates of walls that intersect insulated ceilings. If your drywall crew doesn't want to do that, you can squeeze a thick bead of acoustical sealant in these areas, and you have an instant gasket. See Figures 11.1-11.3 for more about "airtight drywall approach."

Going Further

The EEBA *Builder's Guide* also covers truss uplift, alternative framing for reduced drywall cracks, tub and shower enclosures, and wintertime drywall finishing.

14

Health and Safety

There is increasing concern among the public about indoor air quality, moisture, and mold. There is a lot of confusion and misunderstanding; the media often portrays moisture and mold problems as a result of "tight" construction and energy-efficient design. In reality, most of the mold and moisture problems in buildings result from poor exterior water management, followed by thermal and air barrier defects. We are now using more and more building materials that are subject to damage and decay from moisture, and provide better nutrient sources to mold than we did even 10-15 years ago. In fact, the recent emphasis in codes and building practice on using highly vapor permeable exterior sheathings and highly impermeable interior vapor barriers has led to some dramatic building failures resulting from inward-driven moisture in air-conditioned buildings in the North.

Besides the obvious issues of liability and insurance, any builder or designer who wishes to set him- or herself apart can learn the basics about healthy construction, indoor air quality, and especially mold and water management. While you must be careful not to promise a "mold free" environment, you can certainly create an edge for yourself as a designer or builder of homes with "reduced risk" for mold and other air quality concerns. In fact, these concerns may attract a lot more attention among buyers than energy efficiency! In truth, if you design and build a building to be mold resistant, comfortable, and healthy it *will* be an energy-efficient building as well.

Overview

There are many issues relating to health and safety in residential buildings. Structural integrity and loading of beams, seismic, wind and snow loads, fire protection and egress, basic sanitation, and electrical safety are all covered in building codes and associated mechanical, fire, plumbing and electrical codes. The majority of requirements in most codes are related to life safety issues: prevent the building from falling on people, help get them out quickly in case of a fire, prevent electrocution and fire hazards from wiring, and provide for clean, reliable potable water and waste removal. These are the immediate, obvious health and safety issues which codes quite properly govern to ensure a basic level of security for homebuyers, and a level playing field for builders. Codes that address other health related concerns such as fresh air ventilation standards are often not clearly understood. And there are some less obvious, but perhaps equally important issues that arise in residential building construction. The purpose of this section is to provide a brief overview of the health and safety aspects of the "house system." This summary is only a brief introduction to "healthy construction" concepts; more resources are provided in Appendix B.

Are cars safer than homes?

Not really, but you can think about these health and safety issues in the context of shopping for an automobile. Whether you buy a luxury model, a compact economy car, a gas-guzzling sport-utility, or a race car, you expect a certain level of safety. Even though these cars may perform very differently and fill different needs, they all have seat belts, headlights, and air bags. Similarly, even though houses are designed differently to meet many different needs, they should all have a basic set of protections for health and safety beyond those that are found in building codes. Air sealing and water vapor control is just as critical as a seat belt in a car. A mechanical ventilation system is as essential as an airbag. Sealed combustion equipment and a carbon monoxide detector can be compared to headlights and taillights, and a good exterior water management system is the equivalent of windshield wipers. You wouldn't buy a car without these safety features, and every home should have health and safety as a priority as well.

Priorities

People are becoming more and more aware of the health hazards associated with indoor mold exposure, dust mites, volatile organic compounds, and other airborne contaminants. The incidence of asthma has nearly doubled in the last 20 years, and scientists believe that changes in the indoor environment are the primary cause. Researchers have found that indoor air quality is more polluted—sometimes as much as 100 times more—than outdoor air, and this pollution contributes to allergies, nausea, sinusitis, fatigue, and even extreme chemical sensitivities. In addition, some building scientists suspect that many cases of low-level carbon monoxide poisoning go undiagnosed. Because some people have special health conditions or environmental sensitivities it is difficult to choose a standard that can be applied universally. However, a basic approach to creating a safe, healthy home can be summarized by five principles, all of which involve control of the indoor environment: control of air flows, water vapor flows, energy flows, particulate flows, and pollution sources and flows. The following paragraphs outline the basic approaches to accomplish this level of control:

- **Air flows**—unintended air flows can be unhealthy for many reasons. These air flows can result from the stack effect (uncontrolled infiltration), duct leaks in basements and attics, unbalanced supply and return duct flows, exhaust fans, or combustion appliance makeup air, all of which create air pressures. Low pressures in basements can increase concentrations of radon, sub-soil pesticide treatments, or other soil gases in the home, as well as increased energy loads. High pressures can result in warm, moisture laden air being pushed into exterior walls or into attics and roof systems, where water vapor can condense and cause mold, mildew and decay. Air flows caused by induced pressures or by the stack effect can conduct deadly car exhaust or fumes from stored chemicals from a garage right into the house, or can backdraft combustion appliances. For all these reasons, it is important to reduce or eliminate unintended air flows from homes. The most important methods to control air flows are as follows:
  - Create a very tight building envelope by sealing air leaks
  - Design ducts properly for balanced air flows
  - Seal ducts tightly
  - Install only sealed combustion appliances
  - Design and install makeup air for large exhaust appliances if necessary
- **Moisture flows—**Either too much or too little moisture can be unhealthy. High humidity can lead to increased concentrations of biological contaminants such as mold and mold spores, dust mites, mildew, bacteria and viruses. Low humidity can result in increased incidence of respiratory infections, rhinitis (chronic runny nose), and discomfort. It is generally recommended to keep indoor moisture levels between 30 and 60 percent relative humidity (some experts say 35 to 50 percent, which is very close—also see page 72). To do this reliably year-round you must:
  - Build a very tight envelope to reduce the air exchange that dries air in the heating season and brings in humid air in the summer. This includes tightly sealing any ducts that may be outside the insulated envelope.

- Provide controlled ventilation air to reduce moisture loads in winter.
- Provide spot ventilation for bathrooms and kitchens, and any other special sources of moisture loading (pool, hot tub, fish tanks, etc.).
- Provide dehumidification or air conditioning in the summer. Note that oversized air conditioning will not provide the level of dehumidification needed to keep humidity levels under control; it is actually better to have a slightly undersized air conditioning system for optimum health throughout the summer. With a slightly undersized air conditioner, the indoor air temperature may drift up by a degree or two for a few hours during the hottest days of the year. Indoor air quality, by contrast, will be improved for the vast majority of the humid cooling season.

- **Bulk water** leaking into a home (or from plumbing) can also be a source of high humidity or wet building materials, resulting in many of the same biological contaminants. The following steps are also critical to controlling moisture in buildings:
  - Foundation water management systems, such as capillary breaks, footing drainage, rainwater drainage and grading.
  - Exterior water management systems such as flashing, siding and roofing details, and a properly installed secondary drainage plane (building paper or housewrap) behind siding. Even better is a vented rain screen, with an air space between the siding and the drainage plane. Be especially careful of flashing details where roofs and decks meet vertical walls. (See the EEBA *Builder's Guide* and *Water Management Guide*.)
- **Energy flows—**Limiting energy use in a building is related to health, although less directly than the other approaches in this list. In addition to the increased energy loads that result from large air flows through the building envelope, cold, poorly insulated surfaces may lead to condensation, mold and mildew. It is also possible that when people living in a home are more comfortable, they will tend to be healthier.
  - Select windows that have, at a minimum, low-e glazing and argon gas fills. Higher performance glazings, heat mirror films, "warm-edge" spacers, and insulated frames will all raise surface temperatures and reduce the chance of condensation and fungal growth on the glass and sash.
  - Higher levels of insulation, and framing details that avoid thermal "bridging" of framing from inside to outside surfaces, will also reduce condensation problems and increase comfort.

- Insulate basement walls and slab floors to prevent condensation in the summer, even if they are not in the finished living space.
- Duct insulation and vapor jackets on the exterior of insulated ductwork is critical. Anywhere heating, air conditioning, or exhaust air ducts travel through unconditioned spaces, they should be well insulated, and the vapor jacket on the outside of the insulation should be uninterrupted. Ducts that carry cold air in winter, located in conditioned space or unconditioned basements, should also be insulated carefully with an exterior vapor jacket installed. (Examples include ventilation supply ducts, or the outdoor exhaust duct from a heat recovery ventilator.)

- **Particulate flows—**Most homes have no real provisions for filtering the indoor air. Filters that are provided with furnaces, central air conditioners or heat pumps are only designed to protect the equipment from damage. Better air filters can reduce many of the particles that can cause health problems. High Efficiency Particulate Attenuation (HEPA) filters are the best grade of filter, which may be indicated for people with existing respiratory ailments. It's a good idea to design a whole-house ventilation system or air distribution system with the capability of adding a HEPA filter later, if needed. Avoid electrostatic filters, ionizers, and any air treatment devices that produce ozone. Also note that any filter must be carefully designed into the air handling system, to account for any pressure resistance created by the filter.
  - One advantage of balanced, supply and exhaust ventilation (such as an Energy Recovery Ventilator) is that the fresh air supply can be filtered, unlike exhaust-only systems. Controls are available that keep track of blower run time to ensure minimum ventilation rates.
  - Whole house air circulation with filtration can be provided by the air handler fan of a furnace or air conditioner. Use a low speed setting on the blower with constant or intermittent circulation.
- **Contaminant sources and flows—**This category is last on the list, because it has the least to do with energy; however, reduction of contaminant sources is perhaps the most important priority. Sources are many: volatile organic compounds (VOCs) are found in paints, paint strippers, solvents, wood preservatives, and carpeting, as well as stored fuels and automotive products; formaldehydes are found in manufactured wood products such as interior grade plywood, medium density fiberboard (MDF), carpets, and furniture; stored household chemicals such as cleaning products, aerosol

sprays, and moth repellents are often toxic; and pesticide and herbicide treatments may be present immediately around or stored in the home. Radon gas can be drawn into the house from below the ground, if it is present. Some of these products are not under the control of the builder or designer of the home, but many of them are. Reduction, separation and dilution are the main strategies to reduce contaminant exposures.

- Source reduction is the most effective way to reduce exposure. If you reduce the source, you need less separation and dilution. Use of low VOC paints, glues and finishes, hard surface flooring (wood or tile) instead of carpeting, wood cabinets or sealed MDF, and non-toxic wood preservative treatments all have the potential to improve the health of the occupants.

  Most of these options are within the scope of the builder to influence.
- Separation from the living space of those contaminants that can not be eliminated is the next best strategy to reduce exposure. One aspect of this that is often overlooked is the elimination of unwanted air flows; be sure to keep air that has a high likelihood of contamination away from the people in the house. These areas especially include garages, combustion appliances, and the earth around the foundation. These air flows are under direct control of the builder, although builders rarely pay attention to them.
- Dilution is the last strategy, and by no means least important. Fresh air ventilation is important to help ensure that contaminants that are present (or may be introduced after the house is finished) can be reduced to safe levels. At a minimum every home should have a simple exhaust only ventilation system; balanced supply and exhaust systems with or without heat recovery allow filtration and control the source of the supply air.
- Radon pre-mitigation is a form of controlling contaminant flows. Every basement or on-grade slab should have at least 4" of uniform, washed stone underneath, 1/2" to 1-1/2" diameter, with no fine particles. Put it under the insulation if you are insulating the slab. Radon levels should be tested after occupancy by an EPA-certified lab. If high levels are found the stone will allow for effective sub-slab depressurization with a fan to be added later. At a minimum, install a short stub of 4" PVC pipe vertically through the slab, left 4-6" above and capped off. The bottom end should be in the stone layer. Even better, run the pipe right up through the roof, and if a fan needs to be added later it can be easily installed in the attic with a minimum of disruption.

Appendix A

R-Value/U-Value Average Worksheet

COMPONENT DESCRIPTION	R-VALUE	U-VALUE (1 ÷ R-VALUE)	AREA	U-VALUE X AREA (UA)
			TOTAL AREA=	TOTAL UA=

________ TOTAL AREA ÷ ________ TOTAL UA = ________ WEIGHTED AVERAGE R-VALUE

________ TOTAL UA ÷ ________ TOTAL AREA = ________ WEIGHTED AVERAGE U-VALUE

If you wish, make extra copies of this page. A similar worksheet can be found in the RES*check* support materials from www.energycodes.gov (see Appendix B).

This worksheet can help you calculate the overall R-value or U-factor of groups of components that have different thermal performance. You can use it to calculate the average R-value of two ceiling, wall or floor areas that have different insulation levels; or to get the average U-factor of two different types of windows or doors.

You may find this especially useful if you are using a prescriptive compliance method for a house or an addition. This is the only way that you can get a performance "trade off" using the prescriptive method, although you can only trade off performance within each component type.

The examples on the following page show how to calculate an overall R-value for a ceiling with an uninsulated attic hatch; and the overall U-factor for a group of windows of U-0.36 and a patio door of U-0.42.

R-Value/U-Value Average Worksheet

COMPONENT DESCRIPTION	R-VALUE	U-VALUE (1÷R VALUE)	AREA	UA (U-VALUE x AREA)
attic flat	38	0.026	932	24.5
hatch	1	1	4	4
			TOTAL AREA= 936	TOTAL UA= 28.5

This example shows the effect of a single uninsulated attic hatch on the R-value of a well-insulated ceiling. R-38 is degraded to R-33!

936 ÷ 28.5 = 32.8
TOTAL AREA ÷ TOTAL UA = WEIGHTED AVERAGE R-VALUE

TOTAL UA ÷ TOTAL AREA = WEIGHTED AVERAGE U-VALUE

COMPONENT DESCRIPTION	R-VALUE	U-VALUE (1÷R VALUE)	AREA	UA (U-VALUE x AREA)
windows	—	0.36	239	86
patio door	—	0.42	40	16.8
			TOTAL AREA= 279	TOTAL UA= 102.8

In this example, the patio door has a small effect on the overall window U-value.

TOTAL AREA ÷ TOTAL UA = WEIGHTED AVERAGE R-VALUE

102.8 ÷ 279 = .37
TOTAL UA ÷ TOTAL AREA = WEIGHTED AVERAGE U-VALUE

Appendix B

Resources

Codes

Director, Maryland Codes Administration
Maryland Department of Housing and Community Development,
100 Community Place
Crownsville, MD 21032-2023
(410) 514-7220
www.mdcodes.org

The International Energy Conservation Code (IECC) and the *International Residential Code (IRC) for One- and Two-Family Dwellings* are available from:
International Code Council, Inc.
5203 Leesburg Pike, Suite 600
Falls Church, VA 22041-3401
(866) 427-4422
www.iccsafe.org

The RES*check* software and users guide, the prescriptive worksheets, instructions and support materials are available as free downloads from:
www.energycodes.gov/rescheck

Model Energy Code (1995)
International Code Council
Falls Church, VA
(708) 799-2300

ASHRAE/IES 90.1-1989, Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings
American Society of Heating, Refrigeration and Air Conditioning Engineers
Atlanta, GA
(404) 636-8400
www.ashrae.org

Primary Reference

Builder's Guide-Mixed-Humid Climate (2001)
Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

ENERGY STAR Qualified New Homes and Products

National ENERGY STAR Program
US Environmental Protection Agency
ENERGY STAR Hotline
(888) STAR-YES
www.energystar.gov

Residential Energy Efficiency Programs
Maryland Energy Administration
1623 Forest Drive, Suite 300
Annapolis, MD 21403
(800) 723-6374
www.energy.state.md.us

Foundations and Basements

Building Concrete Homes with Insulating Concrete Forms (1996), an instructive video

Insulating Concrete Forms Construction Manual (1996)

The Portland Cement Association's Guide to Concrete Homebuilding Systems (1995)

Portland Cement Association
Skokie, IL
(847) 966-6200
www.cement.org
www.concretehomes.com

Design Guide for Frost-Protected Shallow Foundations (1996)
NAHB Research Center
Upper Marlboro, MD
(800) 638-8556
www.nahbrc.org

Framing/Alternatives

Cost Effective Home Building: A Design Construction Handbook (1994)
NAHB Bookstore
Washington, DC
(800) 223-2665
www.builderbooks.com

Building with Structural Insulated Panels (2002) by Michael Morley
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

Passive Solar, Windows

Guidelines for Home Building and accompanying *BuilderGuide* (1990) a passive solar design software
Sustainable Industries Building Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

Certified Products Directory (updated annually)
National Fenestration Rating Council
Silver Spring, MD
(301) 589-1776
www.nfrc.org

Residential Windows: A Guide to New Technologies and Energy Performance (2nd ed.-2000) by John Carmody, Stephen Selkowitz, and Lisa Heschong
W.W. Norton & Co., Inc.
New York, NY
(800) 223-4830

RESFEN 3.1 (1999), an energy use calculation software
Lawrence Berkeley National Laboratory
Berkeley, CA
(510) 486-4000
windows.lbl.gov/software/resfen/

Mechanical Systems and Ductwork

ASHRAE Fundamentals 1997
American Society of Heating, Refrigeration and Air Conditioning Engineers
Atlanta, GA
(404) 636-8400
www.ashrae.org

Consumer's Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment (updated twice annually)
Gas Appliance Manufacturers Association, Inc.
Arlington, VA
(703) 525-7060
www.gamanet.org

Directory of Certified Unitary Equipment Standards (updated twice annually)
Air Conditioning and Refrigeration Institute
Arlington, VA
(703) 524-8800
www.ari.org

Duct Leakage Diagnostics and Repair (1995), an instructive video
The Energy Conservatory
Minneapolis, MN
(612) 827-1117
www.energyconservatory.com

Residential Duct Systems: Manual D (1995)

Residential Load Calculation: Manual J (8th ed.-2002)

Air Conditioning Contractors of America
Arlington, VA
(703) 575-4477
www.acca.org

Your Home Cooling Energy Guide (1992) by John Krigger
Saturn Resource Management
Helena, MT
(800) 735-0577
www.srmi.biz

Air Sealing, Moisture Control, Indoor Air Quality, and Ventilation

Healthy House Building, A Design and Construction Guide (2nd ed.-1997) by John Bower

Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings (1993) by Joseph Lstiburek and John Carmody

Understanding Ventilation: How to Design, Select and Install Residential Ventilation Systems (1995) by John Bower

Water Management Guide (2004) by Joseph Lstiburek

Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

The Inside Story: A Guide to Indoor Air Quality (1995), EPA 402-K-93-007

Building Air Quality (1991) 402-F-91-102

Consumer's Guide to Radon Reduction (2003), EPA 402-K-03-002
Environmental Protection Agency
Washington, DC
www.epa.gov/iaq
www.epa.gov/radon/construc.html

Residential Mechanical Ventilation (1997)
Heating, Refrigerating and Air Conditioning Institute of Canada
Mississauga, Ontario, Canada
(800) 267-2231
www.hrai.ca

Insulation

Cellulose Insulation Manufacturer's Association
Dayton, OH
(937) 222-2462
1-888-881-CIMA
www.cellulose.org

North American Insulation Manufacturer's Association
Alexandria, VA
(703) 684-0084
www.naima.org

Energy Efficiency—General

Insulate and Weatherize (2002) by Bruce Harley
Build Like a Pro series
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

Residential Energy (3rd ed.-2000) by John Krigger
Saturn Resource Management
Helena, MT
(800) 735-0577
www.srmi.biz

Publications—Other Books

Canadian Home Builder's Association Builders Manual
Canadian Home Builder's Association
Ottawa, Ontario
(613) 230-3060
www.chba.ca

Green Building Guidelines (3rd ed.-2003)
Sustainable Building Industries Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

Environmental Resource Guide on CD-ROM
Iris Communications, Inc.
Eugene, OR
(541) 767-0355
(800) 346-0104
www.oikos.com

Publications—Periodicals and Catalogs

Energy Design Update
Aspen Publishers, Inc.
New York, NY
(800) 638-8437
www.aspenpublishers.com

EEBA Excellence: Newsletter of the Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

Environmental Building News
Brattleboro, VT
(802) 257-7300
(800) 861-0954
www.buildinggreen.com

Fine Home Building
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com/finehomebuilding

Home Energy Magazine
Berkeley, CA
(510) 524-5405
www.homeenergy.org

Journal of Light Construction
Williston, VT
(800) 375-5981
www.jlconline.com

Product Distributors

The Energy Conservatory
Minneapolis, MN
(612) 827-1117
www.energyconservatory.com

Energy Federation, Inc.
Westboro, MA
(800) 876-0660
www.efi.org

Positive Energy Conservation Products
Boulder, CO
(303) 444-4340
(800) 488-4340
www.positive-energy.com

Shelter Supply, Inc.
Lakeville, MN
(952) 898-4500
(800) 762-8399
www.sheltersupply.com

Tamarack Technologies
Precision Ventilation Products
West Wareham, MA
(800) 222-5932
www.tamtech.com

Organizations

Advanced Energy Corporation
Raleigh, NC
(919) 857-9000
www.advancedenergy.org

Affordable Comfort Inc.
Waynesburg, PA
(724) 627-5200
www.affordablecomfort.org

Conservation Services Group
Westboro, MA
(508) 836-9500
www.csgrp.com

Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

Florida Solar Energy Center
A Research Institute of the University of Central Florida
Cocoa, FL
(321) 638-1000
www.fsec.ucf.edu

National Association of Home Builders Research Center
Upper Marlboro, MD
(800) 638-8556
www.nahbrc.org

Northeast Sustainable Energy Association
Greenfield, MA
(413) 774-6051
www.nesea.org

Residential Energy Services Network
Oceanside, CA
(760) 806-3448
www.natresnet.org

Rocky Mountain Institute
Snowmass, CO
(970) 927-3851
www.rmi.org

Southface Energy Institute
Atlanta, GA
(404) 872-3549
www.southface.org

Sustainable Buildings Industry Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

Appendix C

Lighting

Doing More with ENERGY STAR® Qualified Residential Lighting Fixtures

Consider using **ENERGY STAR Qualified Lighting Fixtures** in your new home construction projects. Lighting fixtures that have earned the ENERGY STAR combine high performance, attractive design, and the highest levels of energy efficiency to save energy and money and help protect the environment. All indoor fixtures are designed to carry pin-based fluorescent lighting, which means the fixture is "hard-wired" for energy savings.

ENERGY STAR qualified light fixtures (indoor and outdoor) are laboratory verified to meet strict efficiency, performance, and durability specifications set by the U.S. Environmental Protection Agency (EPA). All fixtures that have earned the ENERGY STAR mark meet strict criteria for efficacy, color rendition, and color temperature. In addition all qualified fixtures must also be flicker free, emit no hum or buzz, and come with a minimum two-year manufacturer warranty. ENERGY STAR qualified outdoor lighting fixtures also incorporate automatic shut-off during the day (photo-cell) and reduced energy use at night, either through (i) use of an energy-efficient compact fluorescent bulb, or (ii) use of an incandescent bulb with a motion sensor. For more information on ENERGY STAR qualified fixtures, visit www.energystar.gov.

Maximize Lighting Energy Savings by Using an ENERGY STAR Advanced Lighting Package

An ENERGY STAR Advanced Lighting Package Is:

- **An upgrade option** that replaces traditional fixtures in high traffic areas with ENERGY STAR qualified models. (See the table below for the specifications.)
- **Advanced Lighting Technology.** Consumers are increasingly attuned to the benefits of new technology. With the ENERGY STAR package, they can trust that their home will be brightened with the latest in high efficiency lighting technology, without sacrificing anything in terms of aesthetics.
- **A marketing tool** to differentiate yourself from your competition.

Specifications for the ENERGY STAR Advanced Lighting Package

Room Category	Specific Rooms within Category	Minimum Percentage of Required ENERGY STAR Qualified Fixtures Per Room Category
High-Use Rooms	Kitchen, Dining Room, Living Room, Family Room, Bathroom(s), Hall(s)/Stairway(s)	50% of Total Number of Fixtures
Med/Low-Use Rooms	Bedroom, Den, Office, Basement, Laundry Room, Garage, Closet(s), and All Other Rooms	25% of Total Number of Fixtures
Outdoor	Outdoor Lighting Affixed to the Home or Free-Standing Pole(s) except for landscape and solar lighting	50% of Total Number of Fixtures including all flood lighting

* To meet the Advanced Lighting Package guidelines, all installed ceiling fans must be ENERGY STAR qualified. ENERGY STAR qualified ventilation fans and ceiling fans with lighting can be counted as qualified fixtures.

Why is the ENERGY STAR Advanced Lighting Package Good For Builders?

Recognition

Builders can leverage the high recognition of the ENERGY STAR mark among today's consumers and their growing understanding of the need to use energy smartly. The ENERGY STAR Advanced Lighting Package gives the builder new flexibility and lighting package options for their customers.

Enhanced Customer Satisfaction Through High-Quality Products

Builders who offer the Advanced Lighting Package are providing their consumers added value through superior lighting products. The Advanced Lighting Package will save home-buyers money on their electric bills, keep their homes more comfortable because they generate less heat than standard incandescent lighting, require far fewer replacements because lamps last seven times longer, and contribute to reducing pollution. If just one room in every U.S. household was brightened by ENERGY STAR qualified lighting, the annual pollution savings would be equivalent to removing more than 8 million cars from the road.

Flexibility

Builders can choose among "tried and true" lighting options to meet ENERGY STAR guidelines. Preferred designs and options do not need to change.

Differentiation

Affiliation with the government-backed ENERGY STAR program gives the builder an advantage over the competition.

Increased Revenue

Using the ENERGY STAR Advanced Lighting Package enables you to offer a better, higher-end, energy-efficient product that will bring you profits. In addition, the energy savings may allow buyers to afford additional upgrades, further increasing profits.

For More Information

Go to www.energystar.gov and click on the "New Homes" link on the top of the page. Next, click on the Advanced Lighting Package link on the right-hand toolbar, under the "Do Even More With ENERGY STAR" heading.

Or send an email to ENERGYSTAR_ALP@icfconsulting.com requesting additional information.

Photographs courtesy of: Broan-NuTone, Brownlee Lighting, Emerson Fan, Progress Lighting and Sea Gull Lighting. EPA does not endorse any manufacturer.